EDITION B

The Journal of the INSTITUTION OF PRODUCTION ENGINEERS

Vol. XXII No. 3

MARCH, 1943

CONTENTS

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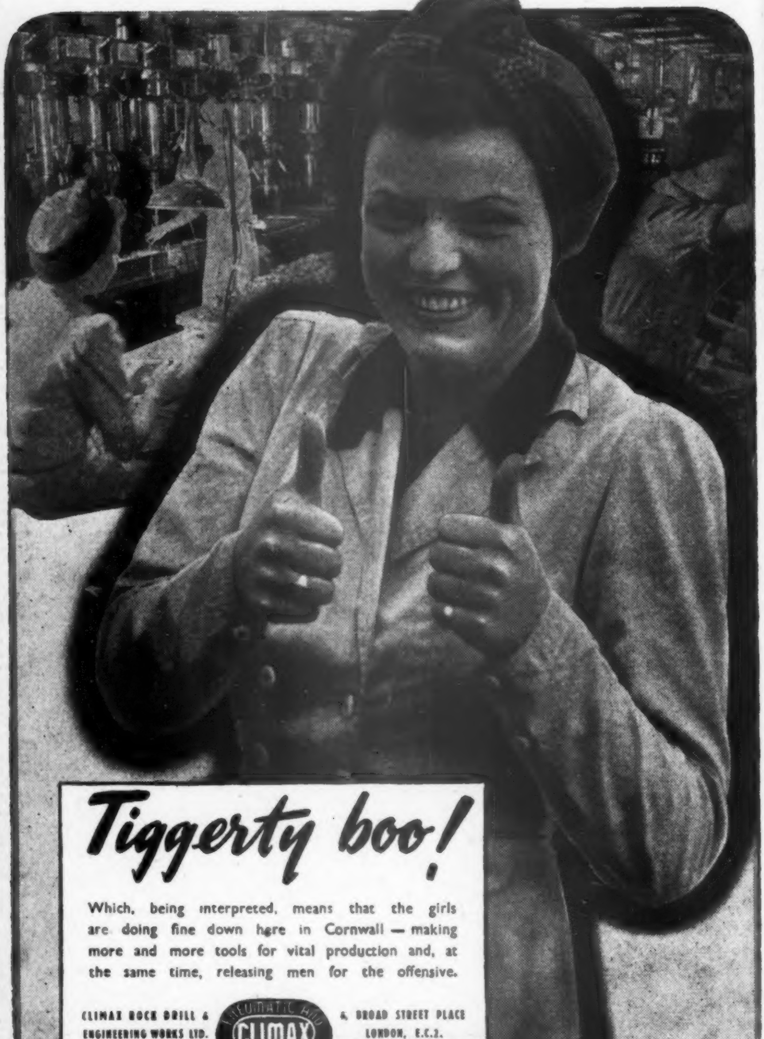
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INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A and B. Advertisers' announcements only appear in one edition each month, advertisements in edition A alternating with those in edition B the following month. This Index gives the page number and edition in which the advertisements appear for the current month.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "The Journal" should not be taken as an indication that they are necessarily available for export.

INSTITUTION NOTES

March, 1943

Fixtures.

April 8—Manchester Section. Annual General Meeting at the College of Technology, Manchester at 6.45 p.m. to be followed by a Lecture at 7-30 p.m. on "Production Control" by R. Appleby, Esq., A.I.P.E. (Ministry of Production).

April 9—Leicester Section. A Lecture will be given at the Leicester College of Technology at 7-15 p.m. on "Plastics" by A. Couzens, Esq., and A. E. Pallet Esq.

April 9—Coventry Section. A lecture will be given at Coventry Technical College, Room A.14, at 6-45 p.m. on "New Tools from Scrap High Speed Steel" by U. F. T. Norris, Esq.

April 10—Preston Section. An informal talk will be given at the Royal Oak Hotel, Chorley, at 2 p.m. on "Changing Conditions in Factories" by W. K. Forster, Esq.

April 22—Leicester Section. Annual General Meeting at 7 p.m. at The Leicester College of Technology to be followed by "The Brains Trust" when a panel of Members will answer questions on Engineering Problems.

Technical Bulletin

At its meeting on March 19, 1943, the Council had under consideration the question of the future publication of the *Technical Bulletin*. In view of the increasing difficulties of obtaining material to maintain a consistent standard, it was decided that in future the *Technical Bulletin* will be published in a new form as and when suitable material is available.

Newly Elected Members.

Members: F. W. Bains, E. J. Davis, F. S. Doxey, G. H. Drake, W. N. Job, A. K. McMorton, W. B. Pilling, J. T. Rymer, A. N. Spriggs, A. White.

Associate Members: R. G. Allen, E. Beaumont, A. Beeching, W. D. Bremer, H. Burden, L. Bunn, J. Bottomley, W. H. Crisp, D. A. R. Clark, A. B. Duncan, P. Dunkley, H. J. Edwards, W. Fletcher, A. L. Hipwell, F. Hodson, W. Holt, W. Hamilton, J. B. Lloyd, S. W. D. Lockwood, W. P. MacMillan, G. E. Moore, A. R. Northover, G. F. Oldham, J. Pearman, W. D. Porter, W. F. Reid, G. H. Rogers, E. Story, H. Shawcross, J. Selby, R. Slater, M. Seaman, W. Van Leer, W. H. Whitehouse, P. T. Wilkins.

Associates: C. A. Bourne, P. Cutler, J. Eden, G. Fefer, H. G. Lee, W. R. Maurer.

Intermediate Associate Members: J. Armstrong, C. A. Atkins, F. W. Bates, L. Bell, F. A. Bowen, A. Bowman, J. S. Barker, W. J. Bailey, M. A. Bull, G. Blachford, H. Barnes, C. E. Butterfield, A. Cameron, E. A. H. Cooper, S. Davey, H. Davenport, W. Dodgson, C. J. Fisher, C. A. Forse, N. Fitton, D. E. Galloway, G. S. Greenfield, J. W. Gardner, G. B. Hart, H. P. M. Haines, C. W. Heath, W. H. Howcutt, E. G. Humphreys, C. P. Homes, J. N. Hemsley, J. Hewitt, H. G. Kippax, E. Lord, R. G. Melton, J. G. B. Morland, T. McEwen, J. D. Mantle, L. J. Martin, G. H. Parry, R. Pattinson, R. D. Preece, C. E. Perkins, J. Rylance, F. E. Riches, J. Russell, R. R. Rogers, R. Siddall, C. S. Tarling, A. W. Turner, E. S. Taylor, G. H. Taylor, G. Walters, W. H. Wallis, J. E. W. Youston.

Graduates : R. L. Aston H. Allinson, K. S. Ayapa, A. F. Abrahams, H. Borley, E. Brecher, E. G. Bradley, J. Baker. M. E. Clayton, W. A. Clennell, T. J. Davies, H. Elkin, H. J. Elmore, F. J. Fudger, J. L. Hepworth, A. E. Hamilton, K. B. Haskins, L. Isenberg, R. Jackson, W. F. Jones, L. C. Jones, F. C. Knott, A. F. King, G. F. Moore, E. C. Marshall, H. E. Nolan, L. H. Osborne, R. Waller, E. T. C. Wheeler, H. Wood, A. Webster.

Students : P. F. Astbury, J. E. Binding, H. Bradshaw, R. Cleary, C. E. Cox, C. W. Cook, D. Caple, P. S. Dunford, W. H. Edwards-Smith, R. H. Eaton, S. E. Fox, D. Foulger, J. Gray, A. E. Griffiths, D. Gittins, J. W. Hallam, H. B. Herbert, S. A. Hughes, K. R. Hunt, G. Harris, A. J. Heushaw, W. Johnson, J. W. Legg, P. H. Leyser, H. Longden, A. W. Markham, S. Millard, F. E. Nichols, E. Pennington, J. W. Poole, D. Potter, J. G. Ross, C. H. Scaife, A. G. Shaw, J. K. H. Smith, A. H. Turner, R. S. Thackwell, P. D. Turnbull, A. Thomas, J. Walker.

Affiliated Firms : Coronet Camera Co. (Aff. Representative : F. J. Pettifer) ; Fred Gilbert, Ltd. (Aff. Representative : F. W. Gilbert) ; Rubery, Owen & Co. Ltd. (Aff. Representative : W. H. Davies).

Transfers.

From Associate Member to Full Member : T. W. Elkington, W. G. Hunt, H. C. Knott, E. G. R. Kipps, J. Millar, J. McI. Shand.

From Intermediate Associate Member to Associate Member : E. H. Bate, E. Charnley, N. B. Hope, J. S. Silver.

From Associate to Associate Member : A. E. James.

From Graduate to Associate Member : J. W. Buckley.

From Graduate to Intermediate Associate Member : F. S. Evans, W. A. Kealy, S. G. W. Lovering, F. M. Lumb, H. Stansfield, E. B. Youett.

From Student to Graduate : L. D. Cammack H. E. Jones, A. W. Millet, C. Ward, W. D. Wilson.

THE YOUNG PRODUCTION ENGINEER—HIS TRAINING AND PROSPECTS

Papers presented to the Institution, Yorkshire Section, by J. D. Scaife, M.I.Mech.E., M.I.P.E., and F. P. Liebert, Grad.I.P.E.

CHAIRMAN : MR. C. W. MUSTILL (opening remarks). First, the Graduate Section will be represented by Mr. Liebert, who will read his paper ; then we are to have a paper which has been prepared by Mr. Scaife on behalf of the Seniors, and this is going to be read by Mr. Hill. Mr. Sykes will open the discussion, and at the same time thank the speakers for the papers. The meeting, gentlemen, is then yours. It is to be quite informal, and it has been decided not to impose a time limit on speakers.

I would, however, ask those contributing to the discussion to make their remarks as brief as possible as time is short.

I am now going to call on Mr. Liebert to read his paper.

Graduate Paper—read by Mr. F. P. Liebert (Grad.).

It is now nearly a year since a Graduate Section of the Institution was formed in Yorkshire, and we welcome this opportunity of meeting the senior members of the Section to discuss a subject which is both important and interesting. It is important to the young engineer because, although he has already finished the introductory stage of his training, he has probably only just started his more specialised training in production engineering ; and it is important to the employer and the fully-fledged production engineer because of the part he has to play in this training.

The experience of one graduate is necessarily very limited compared with that of a senior member, and is hardly sufficient to provide a worth-while contribution to a discussion such as this, in which Mr. Scaife is to take a leading part. For this reason, several graduates have together produced this paper ; but as the subject, even from that standpoint, is very controversial, it is probable that many graduates and students will disagree with parts of it.

Young engineers naturally connect any talk of " training " with their own experiences, but we are going to consider what has been right or wrong with our past training only in so far as it points towards future improvements. For this reason, we have decided to base this paper on the qualities that a production engineer should

possess and the general ways of developing these qualities, rather than to examine in detail existing educational and training facilities which will, in all probability, be unrecognisable after the war : but as we cannot talk of developing qualities until we know what qualities are required, we must first try to obtain a clear picture of what we mean by " production engineering."

Borrowing an idea from Dr. Schlesinger, production engineering can be pictured as a horizontal line cutting through a number of vertical lines, these vertical lines representing various branches of industry such as a wireless or motor-car factory, ship-building yard or chemical plant, or other manufacturing or producing industries such as a rubber works, soap factory or coal mine. This picture illustrates the relationship of production engineering to these various industries, and emphasises that its principles are common to each, but it does not pretend to explain the functions of the production engineer.

The Central Register gives the following definition of a production engineer : " . . . . a staff engineer who normally holds in any engineering works a posiiton of authority involving responsibility for executive management or control (above the rank of foreman) of

any technical function pertaining to production." As this general definition still leaves plenty of scope for disagreement on a subject which we know to be very controversial, we intend to confine our attention to a certain class of production engineer best described by referring to the diagram below which shows, round a circle, a number of departments directly concerned with production in a factory. Our production engineer must be conversant with, and have a good working knowledge of, the principles and systems of most or all of these departments, but we do not consider individuals who specialise in these departments to be production engineers on account of their necessarily limited scope. As an example, a

rate-fixer tends to consider all production methods from the point of view of cost of operation. He might recommend the use of a jig or fixture to reduce the operation time on a large batch, but the production engineer must also take into account other features such as the load on the tool-room and the urgency of the job.

We would emphasise here that our idea of a production engineer is not limited to any one man controlling production in a works, but also incluhes those engineers who are intimately connected with production in all its aspects. For instance, a large firm might possess a complete " production control " department in which there would be, as well as a number of clerks and progress chasers, a small number of qualified production engineers. In a small firm, a works superintendent with an assistant might be sufficient to deal with all production problems, while in an even smaller firm there might be only one man concerned with production.

Our production engineer could obviously obtain the necessary experience (that is become conversant with, and obtain a good working knowledge of the principles and systems of these departments) by spending sufficient time in each to become almost a specialist in it, but this path is weary—one might call it walking round the circle. Many would fall out before completing the circuit because the training is necessarily so extended that there is a danger of their losing sight of the goal, and taking the easier path of remaining in one deartment and specialising in it. This is accentuated by the natural desire of a department to hold on to a man who is of particular value to it. Even though he may complete the circuit, this laborious walking round the circle does not necessarily produce the best engineer, who is valued not by his experience alone, but also by a combination of personality, general education and practical and theoretical training.

For the young engineer, as for all other boys, one of the most important parts of his training is his preliminary non-technical education. This should be followed by a period of general technical engineering education but, before starting to specialise in production, it is essential that the young engineer should have the opportunity of working in at least one industrial establishment and of visiting others. Too early specialisation, both theoretical and practical, is often forced upon the young engineer by the need for adding to the family income directly after leaving school. Where this occurs, it is often found that although at the age of, say, 20 he has a more detailed practical knowledge than the boy who has had the opportunity of a more general education, the latter eventually overtakes him due to his greater ability for absorbing knowledge. The production engineer's training should include experience of all the departments shown round the circle ; although it may not be possible for him to work in all these departments, it should be

possible, while working in some, to grasp the principles at least of the remainder.

In this paper we do not intend to follow all the branches of the family tree which shows the various ways by which a production engineer can be trained. Others better qualified have done this already, and we could not hope to improve on Dr. Fleming's recent review given before the Institution of Electrical Engineers. Instead, we are going to comment on certain features of existing educational systems which seem of particular importance to graduates.

The first point concerns the selection of a career. We do not consider that the young boy interested in engineering is given sufficient guidance in selecting his career. A parent, not connected with the engineering industry, is not a suitable person to advise his son regarding an engineering career. Nor is the advice of friends always reliable. There should be available to the young boy proper guidance on the opportunities which are likely to exist in the career that he fancies. In addition, it should be possible, by some form of psychological test, to determine whether the boy is really suited to such a career, it being remembered that boyhood dreams are not the soundest foundations for his future.

The second point concerns the balance between practical and theoretical training. In existing systems of technical education there are great variations in the proportion of practical to theoretical training. At one extreme we have the day apprentice employment combined with night technical classes while, at the other, we have the University Degree course with little or no attempt to familiarise the student with industrial conditions or even with manufactured products. As an example, one of the first horrors that faces the electrical student at college is the involved diagram of an armature winding. Some attempt to provide a practical background is often made by displaying a solitary armature coil, but how much more easily would the principles have been grasped had the student been given the opportunity of watching an armature winder at work.

Although these are extremes, there are good points in both. The evening class produces engineers with a sound workshop experience, but this road is hard as is shown by the excessive falling off in numbers of students between the first year of the ordinary and the final year of the Higher National Certificate courses. Those completing the course are undoubtedly well-trained, but it is a case of the survival of the fittest. On the other hand, the university course provides a more continuous and less strenuous schooling leading to a higher standard of technical knowledge which, while important to the designer, is not so essential for the production engineer. For him, a middle course (*e.g.*, a part-time day course at a technical college or a university "sandwich" course) is likely

to be the most profitable ; but, whichever is chosen, an essential feature should be effective collaboration between the firm providing the practical and the education authorities providing the theoretical training.

If a firm is in need of a certain number of production engineers, it will obviously obtain the best results in the shortest time and at the least expense by careful planning of each stage of the practical training. This planning should take into account both the theoretical training and the past experience of the individual. The length of his stay in each department and the work he is given to do should be determined by the plan and not by the requirements of works production. Similar planning should also be applied to his later staff training and, again, the requirements of a department should not determine his stay in that department.

The third point is rather different—it concerns the State's responsibility. The basis of practical training to-day is service to a particular employer, who naturally provides this training with a view to fitting the apprentice into his particular organisation.

As we have mentioned before, there is often no connection between the practical and theoretical trainings, although some firms do provide, in addition to an apprenticeship, a theoretical training which is, in one case at least, of sufficient standard to be recognised by the Board of Education.

We are not certain, however, that the basis of service to a particular employer must always produce the best engineer, nor are we sure that the principle is right. Engineering industry requires a certain number of engineers of high standard, and it is in the national interest that these should be forthcoming. Should it not then be the state's responsibility to ensure that the required number of engineers are educated and trained to the required high standard ? State responsibility brings with it some measure of state control, and under this we picture some form of state-indentured apprenticeship with the education authorities responsible for providing suitable practical training.

The future of the young production engineer is governed by two factors—the first local, the second national. The outlook for the individual depends largely on the importance attached to production by the firm in which he is employed. But it depends also to an even greater extent on the man under whom he happens to be working, and on the importance that this person attaches to training his assistants. These are the influences of which he is most aware, but there is a second and equally important factor—the national outlook on production.

At this time, when all attention is focussed on production, the importance of the production engineer is growing. Whether

this will continue depends on the country's attitude to production after the war, and on whether it realises the importance of efficient and nationally-planned production in post-war reconstruction. In other directions there are signs that post-war planning is being tackled intelligently. The suggestions already put forward for the re-planning of London are nothing if not far-sighted, and there are rumours that the Beverage Report on Social Insurance will recommend bold action. We should like to see similar planning for industry, including the provision of sufficient quantities of capable engineers educated and trained on a national basis, and we are certain that, in any such planning, the science of production engineering should be given the important place it deserves.

CHAIRMAN : I think you will agree that the graduates have led off very well indeed, and now I am going to call on Mr. Hill to read Mr. Scaife's paper.

Mr. Scaife's Address

It would not have been difficult in these strenuous days for me to find adequate excuses for politely declining your invitation to address you on this subject, but there are, on the other hand, several very good reasons which made it impossible for me to do so. One of these, and not the least important, is my personal interest in the young engineer, and nothing has ever given me so much pleasure as giving a helping hand to those who have shown a desire to help themselves to become more useful citizens. If, therefore, I can inspire even a few of you with the same spirit of service which has been my own motive force in life my time will have been well spent.

It may be that some of you may be anxious about the future and that, following a period of excessive pressure on men and machines, there will be a reaction to a corresponding period of industrial inactivity, when the services of even the best of us will be at a discount.

This idea is held by many, not all of whom are youthful and inexperienced. Some of them, indeed, are influential and experienced managers and owners of industrial organisations, who base their judgment on the first Great War, and similar, if lesser, periods of industrial high pressure.

To all such who hold that idea let me say at once that my own reading of the "writing on the wall" leaves me in no doubt that the post war period of industrial reorganisation in all manufacturing countries will be on such a scale as the world has not previously seen, and in that statement I do not exclude the remarkable, if not miraculous industrial revolution which has taken place in the U.S.S.R. since the revolution of 1917.

Mr. Eden, the Foreign Secretary, and other Cabinet Ministers, have spoken emphatically on this subject recently and made it clear that the Government is of sheer necessity set on a policy of industrial reconstruction, and that the period of what Mr. Eden calls " Industrial Anarchy " is past.

Industry will be planned on a scientific basis in order to rid ourselves once and for all of the terrible scourge of unemployment which has menaced the world since the *laissez faire* doctrine of Adam Smith sidetracked industrial-social progress in the early part of the nineteenth century.

I am only one of a large and growing number of students of industrial history who are preparing for the future on these lines, and my advice to all young production engineers is to prepare for it also with all the strength and energy they possess to fit themselves for the work which lies ahead. It has so often been said since 1939 that this is an engineers war, but unless my judgment is bad it will be very much an engineers peace which follows the cessation of hostilities ; when the time comes let us see to it that we are better prepared for peace than we were for war in September, 1939.

It is not too much to say that the continuation of Britain and the Empire as a great industrial nation depends mainly on the scientific ability and the adequate supply of production engineers.

We have been called a nation of *shopkeepers* in the past, with some justification, but we shall have to change all that and become a nation of *shop managers* to hold our own in the future.

The economic advantages which this country has enjoyed hitherto, and particularly up to the first Great War, due to our accumulated wealth and huge investments abroad, will have disappeared in financing the present war, and with their passing will have gone the free and easy existence we have hitherto enjoyed. Instead we shall have a standard of life which will be determined only by our skill and success in utilising man (and woman) power and machines to their maximum efficiency.

The bulk of our food and raw materials come from abroad and is paid for by manufactured goods. In the absence of stable currency or even with a managed currency, the value of the manufactured goods will be determined by international competition under barter conditions, and our receipts of imports will therefore be equal to the value of our exports as determined in the world market. That is to say, assuming there is no subsidy, determined by the cost in the most efficient community.

From this it follows that the less man hours required to produce our exports, the more raw materials and food will be received per hour of our time, or to put it in other words, the higher our standard of living.

An important fact which cannot be overlooked and one which

our educational authorities have only recently begun to grasp, is that in regard to the scientific training of personnel for industrial planning and economic manufacture, this country is more than a generation behind Germany and America, and a decade, at least, behind even Russia.

Dr. Schlesinger, the director of our research department, was organising engineering courses in German Universities forty years ago, and fifty years ago American technical journals were being produced for specialists in engineering production. Even at the present time our leading journals which specialise in production engineering literature are off-shoots of the American journals I have referred to, and these have grown more magnificent with the war years, by comparison with our own.

Our backwardness in regard to education in scientific production engineering arises generally out of the inherent conservative of the race and our early success in the industrial era. We are prone to be satisfied with a good article, well enough made to last until the material disintegrates, and to give secondary consideration only to economy of manufacture.

This state of matters has not always been true of this country which was foremost in the mechanisation of industry when the industrial era began in the eighteenth century.

Our success at that time has not been followed up and we have lost considerable ground during the last few generations.

At this stage it is interesting to note that the proceedings of our senior mechanical institution have been confined almost exclusively to the technique of engineering design, and little attention has been given to the economical production of the product.

Also, either due to cause or effect, the university courses in mechanical engineering have been identical with the policy of the Institution of Mechanical Engineers. The combined result of (from our point of view) this attitude of the Institution of Mechanical Engineers and the Board of Education, has left us with a large body of academically highly trained engineers who are, not wholly fitted to play their full part in the present mechanised war effort, whilst we have at the same time a substantial deficit of trained production and planning engineers.

The effect of this has been all too readily apparent from the moment we began to prepare for war.

The Institution of Production Engineers has done a good work during its 21 years of existence in making up the leeway, but the resistance in high places has been tragic and there is much more to be done if we are to win the second " Battle of Britain "—the economic battle.

In that battle it will not be a small band of heroes with insufficient equipment, but a large number of trained production engineers and

managers with ample and efficient equipment which will bring us victory.

In the matter of technical education of production engineers and managers, the older generation has had to shift for itself. Employers were generally not sufficiently interested to grant special facilities and day classes for apprentices were unknown.

A comprehensive study of the ordinary mechanical engineering subjects meant the burning of much midnight oil and drawing on the physical and mental resources of the student.

Strange to say there were many who survived the strenuous ordeal and lived to tell the tale to their less fortunate and enduring fellows, but there were many who fell by the way side on account of sheer physical exhaustion.

This method, being dependent on endurance and will power under adverse conditions, was obviously bad.

Conditions are better today, and fortunately there are few reputable firms who do not encourage their apprentices to take up evening technical school work of some kind.

Even so, there is much scope still for co-operation between engineering firms and education authorities. However, with the development of state aided systems of higher edauction and more highly trained specialists in technical schools this weakness will be remedied.

It is generally recognised now by industrialists and educationalists alike that a primary and secondary school education up to 16 years of age (at least) should precede any technological or professional education.

From my own experience I would say without hesitation that a 16 years old grammar school boy of average mental capacity who receives a well balanced shop training under good supervision will be more advanced at 19 years of age than the ordinary elementary school boy at 21 years of age, and the superiority becomes more marked with further experience.

I am glad to learn from good authority that engineering apprentice training will soon be brought under proper control, and that the present loose arrangement, which in far too many cases has amounted to nothing more or less than the exploitation of cheap labour, with no pretence of a training in craftmanship, will come to an end before very long.

Shop training for a craftsman from 16-21 years of age is probably quite satisfactory for the average youth, but I am strongly of opinion that it is two years too long for technological students who are destined for the higher executive posts in engineering.

These, I believe, will be selected in some manner satisfactory to

industrial and educational authority and will proceed to some State controlled educational establishment of the public school type for two years vocational training by specialists in an atmosphere which preserves many of the best characteristics of the present day public schools. The latter we presume will be non-existant for lack of financial support.

The Public School of the New Order (and which I may say is not so visionary as some of you may imagine) will have for its objective :

1. To develop powers of leadership, sportsmanship, and self reliance in an atmosphere free from the softer influence of home life and fond parents.

2. General education to the University entrance stage and technical education to the ordinary National Certificate examination.

3. Approach to practical technology and elementary machining operations in suitably equipped workshops.

4. Physical culture appropriate to the individual in the widest sense.

At 18 years of age the budding production engineer will then commence a 3 years apprentice course, which will include a general training in machining operations, machine erecting and equipment design.

Nothing in the nature of a privileged premium apprenticeship is envisaged, but strict discipline, good timekeeping, etc., will be part of a sound training. During these years trainees should be required to reach a minimum standard of skill in quality and quantity production before being transferred to another department.

The Higher National Certificate course taken at an evening technical college between 18 and 21 years of age will complete a further stage in the training of a production engineer.

For those who select (or who are selected for) a purely works executive career, further training should continue in planning, equipment design, time study, etc., as circumstances will allow in the particular organisation concerned, after which a minor and progressive post should be sought for the sake of experience.

As a mental recreation I would recommend the reading of good books on industrial history and sociology, so that the student can satisfy himself logically that the mechanisation and organisation of industry can be a benefit and not a menace to mankind. In my own case, it was many years before I was completely satisfied on the point.

A very important part of a production executive's duties is in connection with labour matters, and nothing I can suggest will

provide a better approach to labour problems than a study of human affairs, past as well as present.

While, as I have said, conditions as regards educational facilities are much improved and will undoubtedly be still more improved for the production engineer as educational authorities become more alive to the importance of scientific production engineering in the scheme of things to come, but on the other hand as production planning is further developed, and industry becomes more mechanised, technical ability of a higher order will be necessary on that account and the responsibility of production executives will increase.

The comparatively new production processes such as powder metallurgy, plastic moulding, etc., will be further developed to economise man power and there will be a constant trend to greater accuracy of components by fine finishing to permit more complete interchangeability with the same objective.

Someone once wrote a technical paper on " The Increased Cost of Fine Accuracy," but modern manufacturing technique would unquestionably justify a similar paper on " The Reduced Cost of Fine Accuracy." Close accuracy is now less costly than fitting or even selective assembly.

The new post war national economy will demand production executives of a higher order than this Institution has hitherto envisaged, and for these the title " Production Administrators " might be used.

The production engineer as we have known him is a man of limited scope and outlook. All that we have expected of him hitherto is the ability to produce a prescribed unit or number of units in a given organisation, with a given plant, in a given locality, and probably at a given price, and it does not follow that one of the highest capacity in this sphere would be qualified by nature or training to undertake the higher administrative positions in the scheme of national planning.

For these higher positions an education of University standard is called for and the candidates will be selected at, say 21 years of age, from those who have taken the production engineer's course for the following natural characteristics :—

(1) administrative ability ; (2) strength and integrity of character ; (3) sound judgment ; and (4) imagination, rather than for technical achievements and ability.

The duties of such administrators would mainly consist of :—

(1) Arrangements for the supply of *commodity* requirements ;

(2) Arrangements for the supply of *equipment* requirements ;

(3) Co-operation and collaberation with commodity designers regarding manufacture ;

(4) Economics, wages, etc.;

(5) Rationalisation of production;

(6) Efficient utilisation of national machinery, including man power.

If anyone should doubt the necessity for the type of production official I have outlined, I need only refer to that vast gathering of permanent and temporary civil servants who are now controlling the national supply departments. Composed very largely (the temporary ones at least) of sales, technical and commercial executives of undoubted ability and standing in their own sphere of industry, there is, nevertheless, a lack of production technique in evidence. There was for instance, the government official to whom was allocated the task of preparing the country's manufacturing resources for war, who told some of the leading members of this Institution in March, 1939, that he was quite prepared and there was nothing more we could do to help. I will leave you and Mr. Lyttleton to judge how far he was off the mark, This is indoubtedly an exceptional case, and it would not necessarily be practicable or in the national interest to attempt to redraft the entire administration under present circumstances.

The plain fact of the matter is that our engineering education has been all wrong from the beginning and engineers of the right sort are, as the departments so often say " in short supply."

Fortunately for our economic peace of mind, all questions of administrative efficiency are subordinated to expediency, or in other words " getting the job done," therefore we shall never know what might have been done with an administrative staff suitably trained for the duties involved.

National planning as envisaged by leading cabinet ministers will entail a continuance of industrial control by government departments, but with the important difference that as our essential purchases from abroad will be paid for by manufactured goods, our standard of life will depend on the efficiency of our efforts in the utilisation of man power and machines.

From this it will be obvious to anyone who has been in close contact with the war supplies departments that an entirely different standard of efficiency will have to be achieved in the post war period, or we shall continue with an austerity standard of life in perpetuity, when we might, notwithstanding the ravages of the war, have comfort and plenty with proper and intelligent administration.

The university training for the new production administrators I have envisaged would specialise in the development of the natural characteristics of the selected candidates, and the lectures would continue the accepted university cultural training along with the

study of the special subjects for the duties of the administration already outlined.

Following a degree in production administration the training for government positions should continue for some years in some industrial organisation where economic values can be observed and appreciated. For the higher positions in production administration a substantial revision of the civil service scale of remuneration will be necessary to correspond with industrial standards of remuneration for ability.

I have purposely avoided too much detail and confined myself to what may seem to many of you an optimistic vision of the future. However that may be, there is no alternative for the people of this country to a bare and comfortless existence except that of working themselves out of our economic difficulties by unstinted, unselfish co-operation and the utilisation of every scientific aid available

If I might be permitted to add one final note in conclusion, I would confes, to a slight tinge of envy of the young production engineer who will enjoy a status in the industrial world which we who have reached the veteran stage have had to struggle hard to establish. In regard to your prospects, therefore, "*it all depends on you.*"

CHAIRMAN : I know we shall all agree that the paper Mr. Hill has just read is exactly the sort of paper that we would expect Mr. Scaife to write—constructive and provocative. No doubt subsequent speakers will have something to say on the provocative part.

I am now to call on Mr. Sykes to propose a Vote of Thanks to Mr. Scaife, Mr. Liebert and Mr. Hill.

Discussion

MR. A. SYKES, M.I.P.E., proposed the vote of thanks.

Mr. President and Gentlemen.—It is a pleasure to have an opportunity of thanking the three gentlemen concerned for the way in which they have introduced the subject today. They have put forward their ideas in a very clear cut manner and I feel that a meeting of this kind can do a great deal towards the advancement of the training of production engineers of the future, and by our efforts we shall be rendering service to the industry. Many of us, I think even the youngest of us here, are fairly well advanced in the period of training and perhaps what we are doing will be of more benefit to future production engineers than to ourselves, but even so we are carrying out the ideal of service that Mr. Scaife has referred to. He mentioned it was his ideal to serve the community and I think we can do great service by meetings of this kind.

In thanking them individually, perhaps Mr. Hill will excuse me if I refer rather briefly to him first ; his part was an important one, he read the paper in such a manner that we could understand it clearly and even went back and started again where he thought there were parts we might not have followed. I know very well, if Mr. Hill had taken up the subject himself, he would have made a creditable job of it. He led a discussion in this very room last year, and he introduced his subject on that occasion to the entire satisfaction of the members. Our thanks are due to Mr. Hill and even though he has not compiled the paper, he has rendered good service of another sort.

Mr. Liebert made some apology for having the rashness to address the gathering. He need make no apology to us, the views he expressed would do credit to people of very much longer experience and it is a source of great satisfaction to this Institution to know that we have no lack of young men of such capacity and capability. If he can produce a paper in the way he has done today it gives promise for the future and we need have no fear that the youngsters of the Leeds section will be able to carry on the work of this branch of the Institution.

I feel with Mr. Scaife that we might envy the young production engineer of the future if he can receive training such as has been discussed today.

Mr. Liebert examined the aims of production engineering and when he asked " What are we out to train ? ", " What are we going to do ? ", he realised that he touched a tender spot. I know that even some of the members of the committee have a little difficulty in defining what is a production engineer. We are near the mark in saying he is a man who studies methods of production, the general plan by which work is to be carried out, and the layout of plant, and, arranges the sequence of various operations so that the work can proceed smoothly.

Today we are laying down a plan of training whereas in the past we have not had a clear plan for the training of production engineers. The profession is relatively new ; its inception marks a stage in the development of specialisation, a splitting up of functions as distinct from the more general method of working followed in the past and perhaps in some relatively small shops at the present time where the foreman has to be both production engineer, and progress man and several other functions rolled up in one ; but as industry becomes more specialised, so also do the functions of the engineering works. That is one of the reasons why the production engineer has come into existence and as far as future prospects are concerned we can say it is a new profession and offers wide scope. It is applicable to almost every branch of mechanical and electrical engineering and

the trained production engineer need have no fear as to the scope for his activities.

I agree with Mr. Liebert that he must not specialise too much in the earlier part of his career. We should give a young man the chance of a general education. As he very properly remarked in the case of one whose parents or advisers are not in the industry, it is hardly to be expected that he can make the right selection himself first time. He may find after he has been partly trained that some other line of the engineering industry suits him better than production engineering. For that reason as well as others every engineer should have a broad outlook in his training before he begins to specialise.

Referring again to the definition of a production engineer, in my view, he is a man who studies how, when, and where the work shall be carried out. He does not decide what should be made but he has some little influence on the form it should take ; he is often required to criticise a design as regards its suitability for production and to that extent the production engineer may be a designer, but only in so far as he makes the design more practicable from the manufacturing point of view, without in any way interfering with the purpose which it has to fulfil.

We cannot expect any young man's training to be even approximately completed at the age of 21, it must extend well beyond that time and should be practical rather than academic. There is scope for a certain amount of theory in production engineering, but we should lay more stress on practical experience. I doubt very seriously, for example, whether a university education is an advantage to a production engineer ; the time he will spend there can be more profitably spent in actual workshop experience. On that particular point no doubt some will disagree with me ; we expect at a discussion of this kind there will be different points of view and there will be disagreement.

Mr. Scaife referred to a profession which he called a production administrator. On this point I disagree entirely as I think the particular profession he outlined is outside the scope of the production engineer ; it is something which a good commercial man or accountant could do, without the specialised training which we are thinking of today ; it is more closely allied to the function of the general manager and is only likely to be a wartime requirement. Others might disagree with me and I hope Mr. Scaife will excuse me for disagreeing with him on this particular point.

In setting out what in my view is the ideal course for a production engineer, I feel, like Mr. Liebert, that general education should be the first thing. What I would suggest is, wherever a young man has the opportunity, he should attend a secondary or public school until the time that he has passed his Higher School Certificate—say

about 17½ years of age. By that he will have collected a good working knowledge of mathematics and mechanics, chemistry, sound, light and heat and I think he will have received sufficient theoretical training to carry him a long way in production engineering. Later he will supplement this by evening and part-time studies and he can avoid the gruelling that some of us had to go through in the past. To take the entire course in the evening school is too much to expect and I believe any of us who have gone through that experience will be sufficiently generous not to wish young production engineers to have to go through it. It is not good physically or mentally and it drains the energy of a young man to such an extent that it takes a long time to recover.

After leaving school at 17½ I would suggest he then follows with pattern shop and foundry experience say a year or a year and a half, then three years in various departments of the machine shop to familiarise himself with the operations carried out. Added to this three years he should intersperse a year's drawing office experience on design of the product, not yet having begun to specialise on production engineering at all. By that time he will have reached the age of 23 when he can begin to take up production engineering by entering a jig and tool drawing office or planning office. While engaged in the production office he should continue his studies and aim for the Higher National Certificate, by evening study, combined if possible with one or two afternoons per week day-time study, which most employers are now willing to allow. The latter is a fairly recent development and is in the right direction. We must not tax young engineers and expect too much evening study after a day in the works.

In the Institution *Journal* for July there was an outline of the Board of Education syllabus for the Higher National Certificate in production engineering. It is interesting to read through this in connection with the present discussion as well as the schemes of the various technical colleges which have been designed to meet the conditions outlined.

Personally, I think the syllabus laid down lays rather too much stress on industrial administration and electrical technology; administration is the function of the works manager rather than the production engineer; the latter draws up the plan but it is the business of the works manager or superintendent to carry it out, which is a different matter.

The approved schemes drawn up by technical colleges seem to indicate that they have understood the requirements well. They have added one or two subjects to the general syllabus, for example, they have put in machine tool design, metallurgy and foundry processes, all of which are most useful to the young production engineer.

I would like to refer to another matter, also touched on by Mr. Scaife. It is desirable for the young production engineer to widen the scope of his education. I have no doubt that many of you heard the address by the President of the Institution of Civil Engineers on the October 24, when he mentioned particularly that the engineer is too much bound up in his profession and his interests become narrow. I would suggest that the young engineer should cultivate other interests, for example, the study of one or two languages ; it will undoubtedly be useful to know German and Russian. You may have to travel abroad and have to read foreign literature—it is very helpful to be able to read literature in the language in which it is written.

Another useful and often intensely interesting subject is that of economics. Long before the present war we had learned how to produce better than we had learned to distribute the products. It is no use making things cheaply and in large quantities unless they are going to be made use of and we, as engineers, ought to take an interest in this aspect of our business. Failure to do so might otherwise prove a serious obstacle to our progress.

I noted with interest a reference to the future possibility of control of apprenticeship mentioned by Mr. Scaife and I should be pleased if he could enlarge on this subject. In the past, apprenticeship has been much too haphazard and anyone who takes on an apprentice should see to it that he is given a suitable training. In doing so he is performing a service to the industry but he is failing in his duty if he merely uses apprentices as a form of cheap labour as has often happened. It should not be a question of " What can we get out of the apprentice ? " but rather " What can we put into him ? "

Mr. President and Gentlemen, I hope that I have not taken up too much of your time and it is with the very greatest pleasure that I convey the thanks of the meeting to Mr. Scaife, Mr. Hill, and Mr. Liebert.

Mr. Mustill (Chairman) : I know we are all very much indebted to Mr. Sykes for the delightful manner in which he has opened the discussion.

We have young production engineers present this afternoon, and some who are a little older ; we also have representatives of the great Government Departments which now largely control our lives. We should thus have a discussion which is representative on many points of view.

Mr. R. W. Whittle : For many years I have been interested in the training of production engineers in works, and generally in the technical education of apprentices. In 1906 I formed a class in a large works where we used to allocate one hour to theoretical training and

one hour to practical training each week, the subjects for the succeeding week being selected by each apprentice in turn. They formed an extremely interesting sequence of lectures and discusisons which were frequently referred to in subsequent years in letters I have received from the apprentices.

I would like to suggest that a minimum of seven years should be allocated to the training of all production engineers, the last two of which might be concentrated on the side of accountancy and company and patent law. I have already suggested that our Government training centres should be set aside in post-war organisation for the reception of all leaving school so that they may be submitted to a psychological test over a period of six months to ascertain for which particular trade or profession they are most suited. After this they could be allocated, as at present, to employers who had expressed a desire to the Ministry of Labour for such assistance as these apprentices would afford.

One thing stands out quite clearly and that is that one of the essential features which we must preserve in all our organisations is discipline, and there are indications that in many directions this is being lost to view. By certain inferences from young engineers I sometimes wonder whether the works are being run for their benefit or whether they are there to have a training.

Mr. Sykes has suggested that languages might be added to any hobby which the young production engineer may have in his leisure moments, with which I quite agree. Mr. Scaife, in his paper, has indicated that as this is an engineer's war it should of necessity follow that it should be an engineer's peace, and if this is so, the minds of all young engineers should be so developed as to accept that responsibility. They should be able to control those factors in organisation which will require tact, firmness and a very broad view in all considerations. While we continue to study the scientific side of our business and pursue research to such a degree as possibly to overlook the more essential side of industry (which is the commercial and Academic), and while our technical minds are absorbed in our profession, the plums or administrative posts are being usurped by academicians who have never allowed themselves to wander into the technical avenues which is so confined in its terminus.

I am of the opinion that the time is now ripe when all engineering and scientific institutions should consider the formation of a Parliamentary party and through that party seek to have the necessary representation by putting forward candidates from the funds of the institutions. Thus in all matters involving technical and organising capacity it should not be the prerogative of lawyers and commercial minds to monopolise the administration and direction of affairs, and proceeding logically there would ultimately be found a Ministry of Engineering. The training required for the education of a produc-

tion engineer must be such as to give the four qualities contained in Mr. Scaife's paper, namely, administrative ability, strength and integrity of character, sound judgment and imagination. All these displayed in a full measure should fit any production engineer to take his place as a parliamentary candidate at any future election.

I entirely agree with Mr. Scaife where he suggests that there has been a deplorable lack of production technique in evidence, and I look forward with much hope to the future of production engineers when their education is directed in the manner he illustrates.

Mr. H. C. Newell : It is chiefly with the training of the production engineer that I am concerned, since, if his training is adequate, his prospects are assured.

Mr. Scaife makes reference to the leeway we have to make up in this country in regard to the teaching of scientific principles in relation to scientific planning and economic manufacture, in comparison with America, Germany and Russia. We know this to be true, but the reasons for this lethargy are not so well known. We have been prone to accuse those in high places of inertia and administrative red tape and of inability to appreciate the importance of technical education as the weft and warp of our national fabric, but I suggest that the real apathy against forming a constructive policy in regard to technical education can, and should, be laid at the door of industry.

Twenty-five years ago the captains of industry had no use for a technically-trained man ; these paper engineers who could juggle with a slide rule and find the acceleration of a cam by drawing it out on paper ; they preferred the " real " engineer, who could take his coat off, grab his tools and produce the actual job by trial and error. The technically-trained man of those days had to forget his university training and adopt the new technique of talking " practical " when dealing with these hard-headed bosses.

It must be granted that there existed in this country a few enlightened firms who formulated a constructive policy in regard to the training of engineering apprentices. These policies were translated into workable schemes of full-time and part-time day and evening education by the local education authority, and established in the local technical schools. Funds and equipment were provided (by the firms) and advisory committees set up to guide the training in the desired channels. In this connection, the case of Rugby comes comes to mind. In other cases, the large firms set up schools within their own works and the youths they trained can be found occupying posts of considerable importance throughout the world. How often have I heard it said—" Yes, but only the large firms could do that sort of thing." Surely the reply to this inane remark is—" Why are they large—because they adopted a sound progressive policy in all their activities—not the least of which was education."

We want men of vision—have you ever met a man of vision who was uneducated? I suggest that if the local firms in our manufacturing areas had got together through their employers' associations and decided upon a progressive policy for the training of their apprentices, and then approached the area education authority with their scheme, they would have been welcomed with open arms. If they had helped the local technical school to launch the scheme by offers of modern equipment, and inducements to students such as rewards, time-off for attending classes during the employer's time, etc., this country would not have been denuded of its best craftsmen as it was when the slump set in in 1924. Furthermore, we should have been prepared for the struggle which we are now waging at such tremendous cost to our way and standard of life.

Frankly, the average employer was not interested in the education of his young men. If we hope for better things in the future, we must educate the employer first; if he cannot be educated to appreciate his responsibilities, he can, at least, be eliminated. When the captains of industry realise that service is of far greater value than profit, then will the millenium dawn for technical education and those who serve this calling.

Mr. Scaife condemns the existing university courses in that they produce designers, or the highly trained academic engineer, and ignore the demands of the production engineer. There is a lot to be said for the employment of the highly trained academic mind in the field of production engineering, but I will not labour the point at this stage, beyond remarking that the automobile, aircraft and radio and synthetic plastics industries have benefited enormously by the employment of such men.

In agreeing with Mr. Scaife's remark as a generalisation, I feel the answer is not far to seek. It can be summed up in one word—"staffing."

The university and the technical college believe in catching its staff very young. In the case of the universities the newly appointed lecturer has, generally speaking, had the minimum of workshop or industrial experience and very rarely has he held a post of executive responsibility before exchanging his overalls for the cap and gown. The same is true of technical schools under local education authorities. Young men enter college with good academic qualifications and the minimum of practical experience. Their financial situation improves slightly each year according to the terms of the salary scale. There is no incentive for a technical teacher to venture afield for further teaching experience, because wherever he goes he will receive the same remuneration, unless, of course, he steps up to an administrative appointment. I suggest that if we are satisfied that technical education is important to the industry and the nation, the earnings in education should be comparable with those

of the higher paid posts in industry. If this is recognised, then it should be possible to operate a reversible scheme, whereby lecturers in universities and colleges return to industry periodically and suitable men from industry fill the vacancies in the educational institutions. I understand some such scheme has been in operation in Germany for many years. The benefits of such a scheme would be incalculable. Any change in production technique which was based on fundamental principles could be immediately applied in the classroom and research of all kinds would be stimulated with beneficial effects throughout the Kingdom.

I like Mr. Scaife's suggestion for a public school type of training. There is much to commend it, but there is little point in having a plan, however progressive, unless you have the teacher who is experienced both in the practice of engineering and the practice of teaching. Initially, these people will be drawn from industry but only if the following conditions are satisfied :

1. The status of the technical teacher will compare favourably with that of, say, works manager.

2. The remuneration shall be adequate.

3. Considerable freedom of action shall be granted the specialist in revising his teaching from time to time, as industrial development demands.

4. That it should be a first charge upon either the State or the industry as a whole, to provide the most modern equipment available.

New designs should be tried out in technical institutions first. It is futile introducing modern methods of processing on obsolete equipment ; the technical teacher must be given the best.

5. The differentiation existing between teachers and instructors in most colleges should be eliminated. Pay the man, not the job—salary scales are all right for the average man, but technical education in the future must recruit the exceptional man—equally good in theory and practice.

I am afraid I have taken up more of the meeting's time than I intended, but I will conclude with a brief reference to two other points which I think are important in preparing the ground for the establishment of any schemes of post-war training. I have detailed some faults in the educational system, but it is no use correcting these if industry does not put its house in order. Every firm employing apprentices should give a guarantee to the parent that the youth will be given a " regular " training as a production or mechanical engineer. A personnel officer should be appointed who is a psychologist, or has some knowledge of the subject, and has a working knowledge of the educational and industrial plan. The duty of this official would be to organise and correlate the practical and technical training of each apprentice. In large organisations this

is already being done, but small firms could be grouped into a block wherein the personnel officer would control the training of all apprentices within the block of firms and maintain close contact with the college.

My final point is with reference to the institution qualification. I would like to see the A.M.I. Prod. E. ranking as equivalent to that of the other senior engineering institutions. Our Institution is prepared to accept membership of the Mechanical or Electrical Institutions as exempting from the bulk of the Associate Membership examination, but the I.M.E. or I.E.E. do not accept membership of the I.P.E. as adequate. The present position may have been expedient initially, but the time has arrived when equivalence should be obtained, even at the cost of stiffening the standard of examination for graduate and associate membership. The City and Guilds examinations should not be a basis for exemption.

MR. MUSTILL (Chairman): We have all been very interested in Mr. Newell's remarks as he is in charge of the Mechanical Engineering Department at the Leeds College of Technology.

I am now to call on Mr. Osborne to speak for the Graduates; no doubt he will be critical of certain of the comments already made.

MR. OSBORNE: These few remarks concern one of the points emphasised in the Graduate paper—the importance of planning the practical training.

Some interesting information on this subject of training has been provided recently by a questionaire sent out to the Members of the Yorkshire Graduate Section. The following figures show the number of young engineers who, at a given time, were at each of the various stages of their practical training; but, assuming the figures to be normal, they also represent the average time spent by these young engineers at each of the stages:

		"Adjusted"
Workshop Training	12%	50%
Material Supply and Stores	none	none
Jig and Tool (including Operation Planning)	35%	28%
Ratefixing	3%	2%
Progress	3%	2%
Design	15%	12%
Shop Supervision	8%	6%
Semi-executive, etc.	24%	—
	100%	100%

Some adjustment must be made to the first and last figures—to the first, because many young engineers do not join the Institution until they have completed their practical training, and to the last,

because it is debatable whether this semi-executive stage should be included under "training." I have therefore added a second "adjusted" column in which the 12% for workshop training becomes 50%, and the last stage is omitted altogether.

This gives a more accurate picture and the figures then speak for themselves, particularly where they show the inadequate attention paid to ratefixing, progress and material supply ; but I would like to add a comment on the 12% shown against design, which seems to suggest either that some experience in design is included in production training, or that designers take sufficient interest in production methods to join this Institution.

Mr. Gessler : I am an engineering student of Leeds University and as I have heard so many opinions of the value of engineering studies at universities, I shall try to represent the students' point of view.

One member remarked that for an engineer the university course is practically of no use whatever ; when he comes into industry, he has to begin quite from the bottom. I am not uncritical of engineering courses at universities, because I had some years practical training before and I know that some of the criticism is not unjustified.

But the universities do not attempt to give a complete training to the young engineer. They realise that this is impossible, if only because of the great specialisation today and for the main reason, that into the making of an engineer goes much of that part of knowledge which cannot be learned (or taught) in lectures and which cannot be judged in written examinations. What the university training does is to give a broad outline of the scientific principles and their applications to engineering and a survey of present-day processes and technique. Thus it lays sound foundations for all future studies and at the same time creates a background for the inevitable specialisation.

It is the task of the industry to complete the training and I do not think there are any students foolish enough to think that the university teaches all they need know and that they are fully-fledged engineers when they have obtained their degree. We realise that the most important part of our training came after we had left the university and that contact with practice is most valuable. We should like to have this contact with industry already during our study but there are very few firms who are willing to help us. Of course the fault lies not only with industry. However, it is not enough to sit back and complain that universities are of little use. Make them more useful. Get together with the university authorities and discuss the modifications you think necessary. For instance, make preliminary practical training compulsory ; the minimum duration of this period would depend on

personal experience. Allow lecturers more access to works, so that their contact with advancing technical knowledge is not limited to periodicals. Help them to acquire well-equipped laboratories by supplying instruments and machines on loan or at reduced prices. Encourage works visits. Send engineers and managers to the universities to give talks or short lecture courses dealing with their special tasks, *e.g.*, production organisation, management and administration, maintenance, workers control, time-keeping, rate-fixing, etc. If firms would take a special interest in two or three students of the local university or college, the latter would offer an excellent oppportunity to combine theory with practice. I do not think it would be difficult to modify the timetable to allow for, say one day's factory work in the week. This, of course, should not replace the ordinary practical training before and after graduation. It is only meant to amplify the university course and I feel certain that it would increase the value of a graduate.

It was mentioned in the discussion that engineers take too little interest in the events outside their profession. This is, I think, largely due to the fact the we have been too much concerned with instruction and too little with education. The universities provide an ideal meeting ground on an equal basis for people with widely different views and interests. If the student plays his part in the social and athletic life, he learns to respect other people's opinions, even if he does not share them. He gets to know the reactions of different minds and he learns to find common ground even if interests clash. And sport teaches him that his actions are not only his concern, but affect others as well.

However, only a few outstanding scientists and engineers have applied these principles to the relation of our work to the community. Human beings are more important than formulae and machines, and it is our duty, to treat our work not as an end in itself, but to be interested in the way it is applied. Today, work is the decisive contribution in our fight for survival. It is decisive in peace time. I welcome the call for a parliamentary representation of engineering, because it shows that there is a growing number of scientists and engineers, who realise this need. The young engineer must be taught not only how to contribute to the immense technical advancement, but he should be made to realise that he holds power in his hands, and with power goes responsibility. If the engineer wants to play his part in the administration, he needs more than has been required up to now. He must know what science could do for man and what it has done up to now.

In conclusion, I should like to pay tribute to the very ambitious scheme laid before us today. My remarks were not offered as criticism of the paper, but as criticism of the present state of affairs.

I realise that some firms have done their part in training engineers ; unfortunately they are not the rule.

MR. C. CHEW : It is with some little trepidation that I rise to speak because I am not a production engineer and I have in mind Mr. Whittle's remarks concerning people imposing systems who have no practical experience. I can claim, however, experience in the field of technical education since my calling is in that sphere. I can assure you that the subject of production engineering is very near to Mr. Newell, the Head of our Mechanical Engineering Department.

Mr. Scaife's paper is definitely a step forward and if it were implemented even in part it would do a great deal of good in the industry. I hope sincerely that all those who have spoken in the discussion will later think over the points made and that these will not be confined merely to this section and this room, but that the subject will be discussed on a national basis.

I am persuaded, like Mr. Scaife, that the future prosperity of this country and the empire will be largely dependent as it is today on its productive capacity. If we take the example of a country which is agricultural, its standard of living depends upon its crops and if a drought occurs the crops in that particular year are reduced and the profit of the industry greatly diminished. If Great Britain is to become prosperous the skill of production engineers will be required even more in order to produce materials of all kinds, not only for internal consumption but for export in order to pay for the goods imported. The production engineer, therefore, is going to play a more and more important part in such a future, but a drought in the form of a dearth of skilled men must be avoided.

Mr. Whittle spoke about psychological tests for people intending entering the various branches of engineering and mentioned that he would like to see such tests performed in the Government Training Centres. I hope to touch upon the subjects of these tests later, but would point out here that I think you cannot but agree that the whole tenure of the paper is really the education of the young production engineer as opposed to the narrow sense of training. The training courses such as those given in Governmnet Training Centres are only a small part of that education which properly belongs and should remain in the province of the Board of Education and Local Education Authorities.

It is as well to ask what do we mean by education. This is usually defined in a very general way by educationists as a preparation for life, but we need to go further in the present day and apply it to the realistic existence. This is made up of two functions work and leisure. Clearly education must not only be devoted to vocational training it must also provide the means of making the fullest use of leisure ; consequently I am in full agreement with Mr,

Scaife's statement regarding general education. An individual going into engineering or any other industry should pursue the broadest education up to the age of 16 years in general subjects and then commence his technical education biassed towards the particular vocation into which he is entering. The degree of skill and knowledge required in modern industry necessitates a long training particularly in production engineering, consequently it is essential that people going into it should have the right background on which to build. I do not agree that the standard of the Higher School Certificate is necessary ; the requisite background furnished by the School Certificate or its equivalent is adequate unless the individual is later proceeding to a university. It has been said that a man who can take a first-class in classics could quite well take heat engines in his stride. That is largely true particularly if the converse is included, *i.e.*, that a man who can take a first-class in heat engines could quite well take classics in his stride. The idea that an academic education for everything is to be built up on the classics is more traditional than true. Further, the conception that a cultural education is based solely on the study of certain subjects is one merely of tradition. After all the skill of the engineer can produce objects of artistic quality and beauty, as for example the scientifically streamlined motor car or locomotive, or the poetry of motion of a Spitfire in flight.

We all know that after this war there will be considerable reconstruction in education. Many other industries besides engineering are preparing the ground for the future of their young people and when you come to read over the many reports on this subject it is realised that all the recommendations cannot be brought into effect. One of the changes which will become operative, however, is likely to be the raising of the school leaving age to 15, and later to 16 years of age. I think this will come within a short time of the end of the war and its effect should be to add to the general educational background of the many ; probably vocational training will be introduced at 16.

I was glad to note that in the paper Mr. Scaife recommended a two years full-time course on public school lines. Here I would support Mr. Whittle's recommendation that some psychological tests may be applied at 16 years of age to those youngsters going into production, or any other branch of engineering ; there is, however, something apparently lacking in psychology which is not a sufficiently exact science for us to determine precisely all the factors required for any particular industry, though further research may bring to light methods of assessing the particular factors which denote that a youngster will do well as an engineer. I take it from his paper that he does not intend those two years training in a residential institution to apply solely to production engineers ; that is to say there will be

courses for other industrial personnel on similar lines so that a production engineer under these conditions would in the technical college have the advantage of contact with other types of students to the mutual benefit of all concerned.

There is little doubt that employers generally have not been sufficiently interested in the education of their young employees in the past ; I have had the experience in other parts of the country over a number of years of approaching employers on the question of part-time release for attendance in the technical colleges, but with indifferent results. It is quite true that many young people of 16 who start out to obtain the higher technical qualifications fall by the wayside on the present system. They are required in the ultimate to spend seven or eight years on several nights a week in attending evening classes. This is a great strain over a long period.

The system has one redeeming feature namely that the qualities required in a young person—perseverance, ambition, scholarship, and not the least, a good constitution, are some of the qualities of leadership ; consequently it is not surprising to find that individuals who go through with it often attain the higher posts in engineering and become leaders. We should in a real democracy give them opportunity to pursue their education in the employer's time. After all, half a day, or one day, a week is very little and it means so much to these people at this age. I for one would be glad to agree to dispense with vocational training being taken in the evening. Not that evening classes should be discontinued ; they would still remain for a further education in a whole range of subjects The young engineer should be able to pursue his education in the day on vocational lines and still be at liberty in his leisure time to follow further studies which may or may not be connected with his job, *i.e.*, Economics, Languages, Law, and so on, all of which have been mentioned by earlier speakers.

The idea that education authorities have not co-operated fully with industry is not wholly justified. I am reminded of a conversation between two employers in an industry other than engineering in which the one criticised an educational scheme for certain personnel who were to be prepared for post-war reconstruction. The other remarked that as they, representing the industry in question had offered no scheme themselves, any criticism was ill-founded. My own experience in the past has been that employers in general have agreed as to the value of technical education for the apprentice, but many have not implemented their views by allowing time off in the day.

Industry must make its contribution to the education scheme and if you as an institution desire that all young people in the industry should have a systematic training under congenial conditions it can

be made possible. Technical institutions have been ever willing to offer the fullest co-operation to industry.

Technical educaton has been the Cinderella of the educational world and its large scale developments during the last two decades have out-grown in many cases the equipment and accommodation available. This must be adjusted after the war. If industrialists will play their part in fostering the cause of technical education then it will enter a new era in the near future.

Further, Mr. Scaife has pointed out that we are behind the Continent and America in our provision for technical education. In a broadcast on Stalingrad, the gallant defence of which we have all so greatly admired during the past months, and which many of you may have heard about a week ago, it was stated that there were 21 technical schools in the city for a population of about 500,000. It is little wonder that Russia has shown such a large productive capacity, despite territorial losses, and the main contributory factor is undoubtedly in a system of technical training for production. The importance of this form of education has been, I believe, more fully realised in this country during the present struggle than ever before, and it should rightfully take its place in the future as at least a co-equal partner in the national scheme of education.

I think reference should be made to a possible larger source than hitherto from which young people can be taken into the engineering industry—that is the Technical High School. This development of the present Junior Technical School which from its inception on an experimental basis has developed rapidly as an important reservoir for supplying recruits to engineering. It has not generally received the status it so richly deserves; firstly, because it is a comparatively new type of school and has not acquired the tradition of the older secondary schools; secondly, boys are admitted at 13 whereas the secondary school has previously taken its quota at 11. Again, such schools are housed usually much less favourably than their secondary counterpart. The normal curriculum is liberal and not vocational, and the average product has been proved most adaptable, particularly in engineering.

The consultative committe set up under the chairmanship of the then Mr. Will Spens to report on secondary educaton commended the work of such schools and recommended its transition into the Technical High School. The realisation of this as a further part of post-war reconstruction will place it popularly of equal status with grammar and other schools. Reference to the statistics for the year 1933-4 show that approximately 450,000 pupils were in attendance at secondary schools in this country, whilst about 35,000 were at Junior Technical Schools. The Technical High School of the future should furnish greater numbers of the latter type of boy when the Committee's recommendations are implemented.

Previous speakers have attempted to place a definite age at which the education for the production engineer is complete and the ages of 21 and 23 have been mentioned, but a little reflection will show that education is never complete, even on the vocational side.

In connection with this I would point out that your worthy President has already given notice of a short course to be inaugurated on "Statistical Control of Quality." Courses of this type in technical institutions will be, I believe, an important feature after the war, not due to post-war reconstruction particularly but owing to the need to deal with specialised problems which will come to the fore from time to time.

Mr. Whittle : From the speaker's remarks I hasten to express the hope that my remarks will not be misunderstood. It will be remembered that I distinctly stated when the scholastic career is finished the pupil enters a government training centre. We have spent a considerable amount of money on these training centres and they afford ample opportunity for the psychological examination of all leaving school before they are placed in industry, to avoid the possibility of blind alley occupations.

It should also be remembered that there are Yorkshire manufacturers who have considerably assisted in the equipment of a large technical college. I refer to Halifax where, as a result of my appeal to the Employers' Federation, the present Halifax Technical School equipment is the result, and I feel that Mr. Chew's remarks should not be mistaken as referring to all manufacturers.

Mr. F. P. Liebert : I should like to state on behalf of the Graduate Section how extremely helpful this meeting has been to us all. I know that, if graduates have listened attentively to the various discussions that have followed the two papers, they must have found much help in the fog through which we are all trying to grope our way.

The unamimity shown in the idea that early specialisation should be cut down to a minimum and that general education should be continued as long as possible was particularly noticeable. It is very heartening for graduates to hear this from senior members, and also that less night-school is advocated. On the question of lack of equipment in technical colleges (a point raised by Mr. Newell), I see no reason why the Board of Education should not take over the Government training centres after the war so that the maximum use can be made of the very good equipment which has been collected for purposes of war, using it to train young engineers for the purposes of peace. With regard to the point raised by Mr. Gessler on "Sandwich" courses, there are firms, admittedly not many, who have done a great deal in this line. I myself had a fair amount of practical training during my university training by attending long

vacation courses at various works. Several firms take students straight from college into the works for a year's training before they actually go to the university to get their degree.

In addition, they not only provide long vacation courses for practical training, but also take an active interest in the work the apprentice is doing at the university. When he has obtained his degree they guarantee him a minimum period of two years employment in the factory in order that he may complete his practical training.

Mr. Scaife: Mr. Mustill, gentlemen, I would like to say how very much I appreciated the paper from the graduate section; I think it is a classic, and I think as an introduction to the subject this speaks very well for the graduate section of the university.

I would like everybody who has spoken to have an opportunity of adding to their remarks and amplifying them if they wish, because it is my desire to press this as a campaign on this Institution, and I would like everybody to run over what they have said. Certainly I can't attempt to answer everybody in detail now, but I will reply to all the criticisms and comments in writing to go down as part of the records of the Institution.

The first issue was raised by Mr. Sykes, who questioned the advisability of the production administrators. My reply to that is that the Institution was brought into being as a result of the chaotic production control during the last war, and this paper has been inspired by the fearful prospect of the post-war years unless we can effect a decided change in the quality of civil service administration of industry and commerce.

I think that Mr. Whittle himself answered for me when he said he was in difficulty very often with people in high administrative posts, who hadn't the faintest idea what it meant when we were talking about the planning of production. They are very conversant with our problems, and I am perfectly certain that he agrees absolutely for the necessity of a very keen knowledge of production engineering in the highest places of administration, and it is absolutely necessary in the planning for the future to have people in these high posts who have an idea of planning. Where there has been an absence of that knowledge it has led us into fearful wastage of money, and I do not think I need say anything more than that. It is my absolute conviction that something has to be done about these higher posts.

Mr. Sykes referred to my remarks concerning apprenticeship, but whilst I cannot, at this stage, quote the responsible authority I can assure Mr. Sykes that apprenticeship will, before long, mean a training in craftsmanship and not exploitation of cheap labour as it has so often done hitherto.

Mr. Whittle rather misunderstood my paper when he mentioned that I had cut out a couple of year's training. What I said was that a

boy, properly trained in a general way up to 16 years of age, did not need 5 years training in a workshop to make him an efficient mechanic ; it is not necessary for him to go through 5 years training if he has had a proper school training up to 16. He can acquire the same knowledge in 3 years as an apprentice in 5, that is if he has had proper training at the outset. That has been our experience with our boys, and we have made it a custom only to start with grammar school boys, a policy which has proved very sound and has justified itself absolutely. I can quite understand what Mr. Whittle has in mind, when he suggests, facetiously I think, that production engineers should have a training in law and accountancy, and whilst I can sympathise with the sentiment, I think production engineers have an ample field in which to work. The suggestions I have made will very largely meet Mr. Whittle's point.

Mr. Newell, must, I think, have got a wrong impression from the paper, because I have no criticism of the type of technical education he is concerned with. My complaint is with the universities who bestow engineering degrees on men who have no idea of scientific production methods, planning, etc. Academic engineering without a production engineer's background is little more than useless.

Now Mr. Newell did not like the idea of evening classes. I suggested we should give a boy a general education up to 16, take him 2 years to a public school of the new order for vocational training and that leaves him at 18. I maintain there is no hardship at all for a boy from 18-21 to attend night school whilst having machine-shop training, and I think it is perfectly ideal to have that boy attend evening classes in preparation for the National Certificate of Engineering, provided he is getting experience in the workshop.

If I understood Mr. Chew correctly, he said that the Board of Education would take care of the education (or training if you like) of production engineers but that has not been my experience, as it has taken eight years persistent effort to get the Higher National Certificate Course in production engineering established, and I am quite sure we shall get no assistance from the education authorities unless we fight for it.

Mr. Mustill (Chairman) : Frequently at the end of a discussion the chairman sums up. I am not going to attempt to do that as this subject is far too wide. Instead I am going to make some general remarks.

As one of the many engineers in this room who have suffered under the handicap of long hours of study in the evenings when the body is tired out after a day's work, I rejoice to think a better system is likely to operate in the future.

From the remarks made about public schools it seems generally agreed that changes are certain after the war. I am one of those who

sincerely hopes that the public schools will be retained as in my opinion they form a vital part of our educational system.

It seems safe to say that the opportunities which are open to the young engineer are greater today than ever before. The inauguration of engineering cadetships is only one instance which supports this belief.

Engineers must henceforth play a much greater part in public affairs. As a body we are apt to confine our efforts to purely technical matters. If we do not take a leading part in the general affairs of the nation we must not complain if our social claims are overlooked.

It is true that first we have to win the war but the post-war period must be considered next. This consideration is also a form of relaxation from the burden of the war work we are all performing. It is vital to the prospects of the young engineer that our profession is granted that full recognition to which it is entitled.

I will conclude by thanking all those who have made this meeting such a success. My committee will do all in its power to ensure that full benefit is derived from todays papers and discussion.

Mr. A. White: I think it is appreciated by engineers of my period that the training during the apprenticeship period has materially changed from that experienced by us. In those days, due to lack of specialisation, most engineering shops employed really good craftsmen of very varied experience. The apprentice obtained most of his information from this type of craftsman, and providing he was receptive, was given a very wide training.

Conditions have now materially changed, and in this age of specialisation we are drifting more and more from the complete craftsman and substituting in his place a specialist which leaves a gap in the tuition of the apprentice.

I do not agree with the psychological selectivity before entering industry of a youth for any prescribed training, but would suggest this selectivity should be decided during the first 12 months in employment. With this in mind, I suggest the most desirable training is to leave a boy on a five years apprenticeship, but during this period he should attend 1½ days per week at the local technical college and half a day per week at a class held within the factory. I would suggest appointing to each works a man who has an interest in youth movement, possessing the necessary technical and engineering skill to act as an instructor to the boys, not only in class but on the machines or bench on which they are working. He would be the medium by which information previously given by craftsmen would be imparted to the boy. This combination of practical and theoretical training would show up the boy's high spots, and would enable selectivity to be suitably applied so that his activities are

directed into that channel in which he would prove not only most useful to the nation, but satisfied with his own efforts.

Mr. Whittle discussed the training in accountancy and law, whilst Mr. Sykes suggested languages. I feel that such studies should be reserved for a later period when the boy's engineering training has at least reached a stage of some maturity. I would, however, suggest that in training as a production engineer it is necessary that the student should be given guidance in the analysis of a trading account and particularly on the significance of how establishment charges are derived and apportioned. This will enable him to assess truly the works cost of a machine or department, and provide for efficient loading of machines to produce maximum efficiency.

I further suggest that he must have some experience in a planning department, and if possible in jig and tool design, but I consider ratefixing is not esssential as this can be left to the specialist.

I am of the opinion that the future of the engineering industry of this country will be decided by the effectiveness of our planning, not only in the works, but in the pre-planning of the industry. I am, as you know, a temporary Civil Servant, and know from experience both in the industry and since coming into this department that planning of contracts is the most serious evil of the period.

I was interested to note the suggestion regarding an Engineering Supply Ministry, and feel that the Institution of Production Engineers and the Institute of Mechanical Engineers will have to safeguard the position after the war and ensure that industrialists are used to the fullest extent in post-war planning.

MR. J. P. KENYON : In contradistinction to the statements of Mr. Newell's friend, the title of " Training " is aptly chosen as it is a misuse of terms to speak of the " education " of a production engineer ; no such phase is possible, and I submit there can be no conception of a syllabus that will " educate " a youth to be a production engineer. A youth can receive " education " that will fit him for later " training," the latter phase being the assimilation of knowledge arising out of his own experiences and the experiences of those who have previously trod the same path of practical application.

The purpose of " education " is the process of instruction in the use of natural faculties and it is believed that educational bodies are becoming more concerned with this aspect than with the cramming of the mind with a mass of facts and figures.

I entirely endorse Mr. Scaife's views on the educational side of his paper, viz : Elementary Education at secondary school or grammar school education up to 16 years ; Public school education upto 18 years. It is during this latter stage that a start should be made in the selection of vocational training.

Having determined to embrace the profession of production engineering the youth should begin his practical training by the serving of a recognised apprenticeship which will give him a knowledge of processes and a leavening conception of human nature. During this apprenticeship a Higher National Certificate Course in production engineering should be taken either by day or evening studies.

It is at this stage that I feel Mr. Scaife has taken a "leap into the blue" and a progressive definition of training sequence should have been outlined as it will not fall to the lot of all who aspire, to reach the dizzy height he has set.

Periods of experience should be undertaken in the following works departments, not of necessity in the same firm, during the period 18 to 21 years :—Shop practice—all departments ; inspection ; progress ; time study and rate-fixing ; materials allocation and control ; tool design office, and, planning office ; and on the commercial side in costs and sales departments.

At this stage the Institute should provide both for those "making the grade" (not by set examination, but by the decision of a board on the recommendation of members), and for managements, by setting up a form of bursary, either in conjunction with educational bodies, federations of employers or the Government, for those who are deemed worthy of further training for the higher order of "production administrators."

This higher grade training seems admirably covered in Mr. Scaife's paper.

We should thus have educated and vocationally trained minds at all the important stages of production and for those found not capable of meeting the demands of the Higher Order the door is wide open for managerial and executive posts in industry by virtue of further study in managemental function and a clear understanding of the human unit in industry.

Mr. J. D. Scaife : Replying to Mr. Kenyon's written communication I must share his "disturbed feeling of ineffective effort" but as, to quote Mr. Kenyon's own words I "took a leap into the blue" it will take time and sustained effort to drive home the idea of a vertical development of the functions and influence of the Institution. Horizontal development has been satisfactory during the 21 years of the Institution's life, but to meet the requirements of post-war years we shall have to think in terms of vertical development. If not, even the best of our members will become "hewers of wood and drawers of water" to a race of lawyers and accountants who will usurp the higher administrative positions and activities.

Mr. White's remarks do not call for criticism. In his last paragraph I take it he would agree that civil servants with an industrial background would meet the case.

A SURVEY OF SELECTION AND ALLOCATION FOR ENGINEERING OCCUPATIONS

Frank Holliday, B.Sc., A.F.R.Ae.S.

Introduction.

EVERY year, considerable numbers of quite bright boys and girls enter employment in which they are destined to be anything but successful, and, in many cases, all too obviously, glaring failures. Every year, too, very large numbers of men and women change their employment, many of these for no apparent reasons. Boys are accepted as apprentices to a skilled trade whom time shows will never become skilled men; pupil apprentices embarking on an apprenticeship find, as time goes on, that their initial keenness is slowly but surely being chased away by the hard knowledge that a career in engineering is not what they thought it was. Men accepted by the armed forces for rapid training in a skilled trade simply do not "make the grade" and have to be down-graded and replaced by others with whom a fresh start has to be made at the bottom of the ladder. Men are accepted by engineering firms on the basis of past experience, perhaps on the full rate as centre-lathe turners, who a very short time shows will never be top-rate turners whatever else they will make. The toolroom foreman, endeavouring to do his best at a time when juvenile labour is desperately short, is faced with the hopeless and discouraging task of endeavouring to train as potential toolmakers a number of boys in his department whom he and his chargehands know only too well have little, if any, chance of ever making toolmakers. In another part of the works, boys are doing monotonous repetition jobs who are just the material the toolroom needs for its next generation of toolmakers. Women are engaged as capstan operators who would be rapidly trainable as inspectors; others engaged on fine electrical assembly who simply lack the rapid finger and hand dexterity the job demands. And so on. Obviously, examples of this nature could be multiplied *ad infinitum*.

The resulting wastage—mental, physical, moral, and financial—is simply enormous when integrated over the whole of British industry. Direct loss of production is the most obvious cause of bad selection, but not by any means the only one. "Most factory doctors," writes one experienced investigator,[1] "would agree that to say that a third of all sickness absences are psychological in

origin would be an understatement." Excessive absenteeism and sickness, real and feigned, worry through the feeling of being unequal to a job, discontent through being too good for it, lack of interest, application and initiative, a low standard of work, an increased amount of spoiled work and of accidents, shop and office friction, a high turnover, with its concomitants of high financial wastage, lowering of morale and slackening of *esprit de corps*—these are merely *some* of the results that bad selection brings in its wake.

The loss resulting from a high labour turnover is due to various causes; cost to the Employment Department in advertising or otherwise securing applicants, and cost of interviewing them, cost of using skilled workers to train new-comers, reduced output of new-comers during the training period, mistakes made by new-comers, causing accidents, spoilt work or machinery, and disturbance to morale within the firm. Sargent Florence[2] estimates that a labour turnover of 100% per annum would cost British employers and workers £100,000,000. Two investigations into the labour turnover in the London district[3] and the Leeds district,[4] and relating to 54,257 and 10,082 employees, and to 78 and 44 firms respectively, showed the magnitude of the actual labour turnover, and emphasised, moreover, that a substantial percentage of it was avoidable. After the outbreak of war, the labour turnover rose dangerously and the Essential Work Order, 1942, certainly has eliminated much of it, but clearly, this cannot solve the numerous problems connected with bad selection. As Guy W. Wadsworth, Jr., Personnel Manager of the California Gas Company, points out,[5] ". . . very often the really important turnover is that which does not occur." Because " it costs money to train men " there is pressure against firing even probationary employees unless they commit high crimes. As a result, payrolls include people whose retention appears to represent " good turnover " but who may be very sad examples of hiring. The employee who actually falls short of making good, but who nevertheless is kept on the job, represents a far greater expense than would moderate turnover."

England lags badly behind America and other countries in the experimental investigation of any and all problems connected with what may be called " the human factor "—and for two reasons, it seems to me. In the first place there is little, or at the most, a very inadequate realization that many of these problems exist, less realisation still of their nature and implications, and almost no recognition at all that they might be susceptible to experimental investigation. Just recently the Minister of Aircraft Production was quoted in the press as saying that the aircraft industry had pretty well all the labour it could expect, and that means other than drafting more labour into it would have to be adopted to increase production still further. Despite the now considerable

amount of work that has been done on industrial selection and allocation, the official mind gives no inkling whatever of being in the least aware of it—none is so blind as he that will not look.

It is axiomatic that a person well fitted by nature of his talents and temperament for a job is likely to do better at it than another not so fitted, but is it realized that it is a fact that individual differences in output of equally experienced workers are often of the order of 50% or more, and that differences of 100% are not at all unusual? These individual differences are not accountable for entirely by differences in endeavour and—strange though it may seem—do not disappear even on the subtle introduction of the inevitable "bonus." They must ultimately be attributed to a difference in endowment; one person is well adapted to the job, another less well adapted to it.

The Economic Case for Careful Selection and Allocation.

The economic case for the wider application of systematic selection and allocation in industry is unanswerable when the vast sums wasted are realized—and every scientific, *i.e.*, exact investigation has shown indubitably that the financial wastage *is* enormous —and when it is realized that the cost of more effective selection may not be large and may, in fact, be extremely small, if a modest programme is embarked upon. R. Randall Irwin, Manager, Industrial Relations, Lockheed Aircraft Corporation, Inc., states in an article[6] on his company's testing programme that approximately 40% of the cost of an aeroplane is devoted to wages and salaries, which exceeds the amount spent on materials and parts. Assuming this percentage and a relatively small turnover of £1,000,000 per annum, a company's annual wage bill would be £400,000. The most optimistic industrialist would admit I think, that, at the barest minimum, 5% of this, or £20,000 is waste, and so I suggest that it would merely be sound economic policy for the company to allocate, say, one-half of one per cent of its wage bill, *viz*: £2,000 per annum, *i.e.*, one-tenth of the minimum wastage, purely experimentally for a period of, say, three to four years, in order to investigate whether or not the wastage could not be improved upon. I have no doubt at all that the work, in competent hands, would pay for itself several times over.

A concrete example may be given. The author has been carrying out an investigation [7, 8, 9] into the selection of trade and pupil apprentices in his firm, in such little spare time as he has had in the last four years. A preliminary enquiry pointed to alarming wastage—no less than 17% of a substantial number of pupil apprentices volunteered the information that they felt quite unfitted to be engineers, and these were intelligent youths, all with more than two years' experience. The actual percentage of a sub-

stantial number of apprentices whom subsequent experience showed to be unsuitable was certainly not less than 20%—in addition to which the general standard of efficiency of apprentices, both in their shops' work and in their studies, was low. Assuming the firm has 100 apprentices earning on an average £2 per week, the apprentice wage bill is £10,000 per annum. The immediate minimum wastage was, therefore, £2,000 per annum (but since the failures will very probably not stay in the industry, the whole cost of their training may be regarded as waste). During the last three years the author has been using psychological tests to aid his recommendations to his management. The *overall* cost per annum of selecting apprentices from over 100 applicants is of the order of £50, and for this the 20% wastage has been reduced to 1 or 2%—a saving of nearly £2,000 per annum. Further, setters, chargehands, foremen, heads of departments, etc., who were unaware that tests were used in the selection of apprentices have, on many occasions, volunteered the information that the earlier apprentices did not compare with the later ones. Many apprentices have been upgraded to the Drawing and Technical offices and to the Inspection, Ratefixing, Planning Departments and Estimating Office and they are certainly among the best juniors in their departments. Things are not perfect but they are certainly much better than they were—a result which has been achieved, I repeat, at a cost negligibly greater than would be incurred if apprentices were selected by interview with the Apprentice Supervisor and considerably *less* than would be incurred if they were selected as a result of a board interview at which highly paid officials such as the General and Works Managers were present.

The Psychological Basis.

The following may be quoted from the 48th "James Forrest" lecture,[10] delivered in January 1942, by Dr. C. S. Myers to the Institution of Civil Engineers :—

"It is widely recognised now that in very varying degrees a single 'general' factor of intelligence is involved in all forms of purposeful activity ; and that there are also a considerable number of 'group' factors, each of which is common to a particular group of activities, and of 'special' factors, each of which is peculiar to a single, simple form of activity. There is undoubtedly a group factor underlying 'mechanical' and certain other abilities, which concern the readiness to perceive the sizes, shapes and spatial relations of objects. With this 'spatial' factor certain tests that have been devised prove by mathematical analysis to be highly saturated. In the daily work of the engineer this factor is involved in his translation of two-dimensional diagrams into three-dimensional objects, and *vice versa* (as in the reading and making of drawings), in the pattern-

maker's and moulder's ability to imagine the 'inverse' of a pattern or object, etc. There is reason to believe that it is also involved in the engineer's "machine sense," as shown in his ability to realise how a machine works—how its parts fit together, how, if one of the parts is set in motion, another will move, etc."

Many years' work has established the value of intelligence and aptitude* tests beyond a shadow of doubt; intelligence tests are now officially recognised by the Board of Education and are being increasingly used by Local Education Authorities, as are also aptitude tests.

The bearing of recent psychological findings on selection may be seen from the following brief illustration. General intelligence is related much more closely to academic success than it is to success at toolmaking, which latter implies good endowment with, among other things, the group factor mentioned above by Dr. C. S. Myers, which is relatively independent of general intelligence. Certain fine assembly work involves the exercise of accurate and nimble manipulative ability, which is much more important for success in the job than either general intelligence or the abilities covered by the "mechanical" 'group' factor.

The need for a close analysis of each occupation—mentioned later in this article—now becomes apparent. Besides giving a brief, straightforward account of exactly what is done, and the materials, tools and processes involved, this should state not only what qualities of physique, character and temperament are necessary and desirable for success in it, but what abilities and to what extent. It may then be possible to design tests to measure these abilities.

In vocational guidance, where an attempt is made to give advice as to the sort of job which should be taken up, or as to which one of several main occupational channels should be entered, it is clear that, the number of tests which time permits being limited, these will aim at assessing the most all-pervasive of all mental abilities, general intelligence, as well as some of the abilities covered by the more important 'group' factors. In vocational selection, whilst tests of general intelligence and of the relevant "group" factors will probably find a place, other tests of "special" factors may also be desirable or, in fact, essential. Just what tests are used will clearly depend on the nature of the job. There are a number of different kinds of tests. Tests of intelligence may be oral, pencil-and-paper or performance tests and the pencil-and-paper tests may be verbal (*i.e.*, employing the medium of language) or non-verbal. Aptitude tests may be analytic tests of the pencil-and-paper or performance types or analogous or sample tests, in which latter case

* An aptitude may be described as a potential ability, *i.e.*, it may, through training and/or experience, become an ability which shows itself in skill of one sort or another.

they reproduce elements of the job. Some tests are individual tests and some group tests, which may be given simultaneously to a group, with a consequent saving of time.

It may be remarked generally of reputable psychological tests that their design and standardisation is a long and skilled job. The questions in them are not "trick" questions and in pencil-and-paper types there are usually a large number of short questions. The instructions for each test are carefully standardised and it is usual nowadays to give one or two practice examples to ensure that the candidate has "got the hang" of what he is required to do. The questions are carefully graded in the order of difficulty found experimentally with groups of substantial size. Every candidate can get some answers correct. The idea, to borrow an analogy from high-jumping, is not to set the "stick" so high that some of the candidates cannot clear it, but to set it low to start with so that all can jump it and then gradually to raise it until, one by one, the candidates fail to clear it. If the test is well designed and properly administered the candidate's score on it should show his "ceiling." Many tests are of the "multiple-choice" answer type, *i.e.*, several answers are given and the candidate is required to pick out the correct one. The marking is objective—a great asset, and it is possible, as the number of candidates who have worked the test grows, to build up norms of performance.

Vocational Guidance.

Clearly it is very much in the best interests of British industry that machinery should be set up on a nation-wide scale for the giving of sound vocational guidance. The National Institute of Industrial Psychology has a department for this purpose and it is able to report[11] as a result of a follow-up relating to 639 cases, that the successes are fifteen times as frequent as the failures where the Institute's recommendations have been followed, and only about twice as frequent where they have been rejected. All boys and girls leaving schools under the Birmingham Education Committee are given vocational advice, but, generally, this country has made nothing like the progress that others have in this sphere. In Spain, for example, the Bureau of Apprenticeship created in 1915, was transformed in 1918 into the Institute of Vocational Guidance and made rapid progress, particularly after the appointment in 1920, as director, of Prof. Emilio Mira, who subsequently became chief consulting psychologist to the republican forces during the Spanish Civil War. This progress is undoubtedly to be attributed in a large measure to the fact that industrial psychology—which includes within its field the problems of vocational guidance and selection—was from the beginning sponsored by public authorities. When Señor César de Madariaga, an eminent Spanish industrial engineer,

was appointed Director General of Vocational Education in the Spanish Government, he secured official legal status for vocational guidance. At the same time he also effected far-reaching reforms in vocational education and apprenticeship, in which an important place was reserved for the vocational adviser and for the industrial psychologist[12].

The Industrial Fatigue (now Health) Research Board collaborated with the National Institute of Industrial Psychology in 1922 in a joint preliminary investigation—the first one in this country—into the value of scientific vocational guidance. A full account of this is given in the Industrial Fatigue Research Board's Report No. 33[13] and a more general account elsewhere[14]. The subjects of the investigation—52 boys and 48 girls between the ages of 13 and 14 years, who were due to leave three schools of a London Borough within the next year—were given vocational advice and followed up in their jobs for a period of two years. The successes and failures were related to the advice given. The report states (p. 98): "The general outcome of the inquiry speaks strongly in favour of the methods used. The scheme has proved workable; the results unexpectedly successful. Judged by the after-histories of the several children, those who entered occupations of the kind recommended have proved both efficient and contented in their work. As compared with their fellows, they are, on an average, in receipt of higher pay; they have generally obtained promotion earlier; they have experienced fewer changes of situation; and have occurred hardly a single dismissal between them. Over 80% declare themselves satisfied alike with the work they have taken and with their prospects and their pay. On the other hand, of those who obtained employment different from the kind advised, less than 40% are satisfied. Among the latter group nearly half dislike their work; and among the former only one dislikes it, and that simply because it is not quite identical with what was originally advised. No great weight can be attached to these figures; yet, so far as they go, they are certainly encouraging."

The results of this preliminary investigation having been so promising, the Institute embarked on a large-scale experiment covering 1,200 children (600 forming a "tested" group and 600 a "control" group), who were followed up for a period of upwards of four years. This long and arduous London investigation[15] emphasised the tentative conclusions of the first investigation; and in turn its conclusions were emphasised in another substantial and important work carried out in a different geographical area—Birmingham—for the Education Committee of that city by a member of its Juvenile Employment and Welfare Department and by a member of the staff of the National Institute of Industrial

Psychology seconded to Birmingham for that purpose. A brief and clear summary of the work is given in the last of two reports[16] issued on it and striking evidence was obtained of the value of scientific vocational guidance.

Work Bearing on the Selection of Apprentices for the Engineering Industry.

The Birmingham researchers also carried out an extensive investigation to discover how far it is practicable to use psychological tests in the selection of boys for the skilled engineering trades[17]. A " battery " of tests was given to a substantial number of boys at a Birmingham Junior Technical School and to third and fourth year apprentices at the Birmingham Central Technical College. The tests were also given, for purposes of comparison, to boys at a Commercial and at a Secondary School.

A very substantial agreement was found between the scores of the boys at the tests and their instructors' independent gradings of them for "apprentice ability," and this agreement exceeded 90% when allowance was made for adverse temperamental traits observed and recorded systematically at an interview or later. The reliability of the tests over the period of the normal two-year Junior Technical School course was proved and a follow-up in industry over a period of 2½ years of 157 ex-Junior Technical School boys was made, information being obtained from both the boys and their employers independently as to the suitability of the former for their jobs. It was shown that more boys doing well in the Test Battery than in the academic entrance examination (a) entered, and (b) were subsequently successful in engineering and allied trades. The results of the Test Battery gave a more reliable indication of the boys' success at the end of the two-year Junior Technical School course, so far as engineering subjects were concerned, than did the results of the academic entrance examination.

Psychological tests have now been introduced as a routine measure in the selection of boys for entry into the Junior Technical Schools of Birmingham and other authorities are endeavouring likewise to improve their Junior Technical School entrance examinations.

A report issued early in 1939 from another source[18], states: "Sufficient evidence is now available from a number of surveys that special aptitude tests covering artistic, mechanical and manual abilities made at 13 plus are of good prognostic value, as proved by school records and success during apprenticeship. The evidence suggests that all candidates for entrance to the Junior Technical School could well be subjected to Group Performance tests of this type, and in border-line cases to Individual Performance tests as well, with a view to ascertaining whether they possess in any

marked degree that practical ability which is a necessary prerequisite to success in constructive jobs."

Another and more recent report[19] gave a summary of a research in which the positions of 109 boys of 13 plus in (a) an academic form of entrance examination, as a result of which they entered a Junior Technical School, and (b) a number of psychological tests, separately, were compared after one year, with the ratings of the boys in 8 subjects by members of the school staff. Some of the tests—taken separately—agreed with the criterion as well as the entrance examination, which occupied more than 6 hours, and three gave a rather better agreement. Statistical analysis showed that had four of the tests been suitably weighted the net result would have given a distinctly better agreement with the masters' rating than the entrance examination.

It may be remarked here that the present position relating to entry into Junior Technical Schools is eminently unsatisfactory. These schools select from Central School boys at 13 plus, *i.e.*, after the cream of the elementary school boys have been absorbed into Secondary Schools as a result of the junior scholarship at 11 plus. It is true that a percentage of Secondary School boys later enter engineering but it is deplorable that, in an industrial country, schools, the majority of which cater specially for the engineering and allied industries, should have to select from material which is obviously intellectually inferior to that from which grammar schools select their boys.

Dr. R. H. Stanbridge has given an interesting account, in an article published in 1936[20], of some work which was commenced in 1932, on selecting aircraft apprentices for the Royal Air Force. In it he points out that aircraft apprentices who enter the Service at from 15 to 17 years of age are allocated immediately to one or other of the vacant trades and discusses the factors tending to produce misfits and the effects of unsuitable selection. During the course of the investigation which he describes, entrants were interviewed, given a physical examination and also three mechanical ability tests, two of which, the Halton and Cranwell tests, were devised as a result of observing the nature of the work required in the workshops where, in the case of Halton, the trades of engine fitter and aeroplane rigger, and, in the case of Cranwell, instrument-maker and wireless telegrapher were taught. At a collective examination, the National Institute of Industrial Psychology's Group Test of intelligence, No. 33, was given, together with a mechanical aptitude and a perseveration test. Reports were then forwarded to command headquarters, where detailed records were also kept of each boy's progress in his squadron, school and workshops, etc. By the Spring of 1936 a total of some 1,100 examinations had been

made and two complete entries of apprentices had completed their courses and had passed out as trained mechanics.

The Medical Research Board—which has under its control the Industrial Health Research Board—made a statistical analysis of the results. Entrants had been assessed into three main groups, *viz*: (a) those likely to do well, including potential cadets, (b) those unlikely to do well, including those considered unsuitable for the Service, and (c) others, *i.e.*, (i) those who should have had a different trade, and (ii) those needing further observation on physical grounds. These were compared with the three passing-out ranks of (1) cadets and leading aircraftsmen (L.A.C's), (2) aircraftsmen-first class (A.C.1's), and (3) aircraftsmen—second class (A.C.2's), and cases discharged from the Service as being unsuitable. It was found that class (a) contained three times as many cadets and L.A.C's as would be expected by chance and contained no A.C.2's or discharges, and that class (b) contained no cadets or L.A.C's but over twice as many A.C.2's and discharges as would be expected by chance. This tendency was consistent in both entries.

In the first entry, 138 boys were trained, of whom 14 became cadets and L.A.C's. If these boys had been chosen by the assessment mentioned above it would have been necessary to train only 123 to yield the same number of cadets and L.A.C's, *i.e.*, there would have been a saving of 10.9% in the number of boys trained. The average saving in both entries was 10%. The general conclusion was that there was every reason for supplementing the ordinary entrance examination by psychological tests. It may be observed here that there is little doubt but that if new and improved tests developed since 1932 had been used, the results would have been appreciably more striking .

The author has been carrying out an investigation, to which reference has already been made in this article, into the selection of both pupil and trade apprentices in a large engineering firm, since 1938. He has used a group test of general intelligence and a battery of pencil-and-paper aptitude tests, and has tested to date 126 pupil apprentices and 136 trade apprentices, and, in addition, 163 unsuccessful applicants—a total of 425 boys. It may be said at once that the first 18 months' research gave such promising results that these psychological tests have been used *as an aid* to selecting apprentices since the Spring of 1940. The tests were themselves first tested, *viz*; a comparison was made between the gradings based on their scores on the test battery of nearly 100 existing apprentices who (when the tests were given) had been in the firm for between six months and three years, and, among other things, the careful gradings of their "general apprentice ability" made after a further fifteen months by the Apprentice Supervisor (not the author). At that time there were only two

groups sufficiently large to warrant analysis, but in both these—a group of 30 pupil and another of 41 trade apprentices, the agreement was good—the cases of agreement occurring, on an average, nearly five times as frequently as those of disagreement. During the testing, systematic observations were recorded on certain traits of personality, which were considered important occupationally, and were relatively independent of one another and clearly definable, and when account was taken of these the agreement mentioned above became of the order of 95%. Later, applicants for apprenticeship were, of course, interviewed and during the interview and after it further observations were recorded; the method and technique of interviewing—difficult matters—have now been considerably improved.

Apprentices have been, and are still being followed up with great care and in considerable detail in the Works, in the Drawing and technical offices and in other departments of the firm, and in their classes, which range from preliminary technical and trade classes to Ordinary and Higher, Mechanical and Production Engineering National Certificate, and Intermediate and Final B.Sc. (Eng.) degree classes. Works and departmental reports have been obtained at three-monthly intervals since the autumn of 1939, although earlier reports exist, and follow-up information in this connection extends, in some cases, over six years. Considerable follow-up information has also been collected in connection with apprentices' studies. It has been shown that scores on the aptitude tests are related to subsequent proficiency in skilled work generally in the shops and, in particular, in success in engineering drawing. Scores on the intelligence test also are strikingly related to success at mathematics in particular—a subject of fundamental importance in most engineering studies—and to academic success generally. Evidence emphasising the existence of aptitudes relatively independent of general intelligence, yet of considerable importance in engineering, points to the unique value of reputable psychological tests as an aid to selecting apprentices.

The marked improvement in the successes of apprentices in their studies and examinations has been observed elsewhere[9] but the following further example may be instructive:

The percentages of total passes to those sitting, averaged over 3 subjects, and over 7 Technical Colleges in the county, for the students (excluding the apprentices covered in this investigation), for the Second* Year National Certificate examinations in 1940. 1941 and 1942 were 60.3, 64.1 and 64.8% respectively. The cor-

* The *Second* Year (Ordinary) National Certificate course in Mechanical Engineering examination results are given here because, at the time of writing, no other complete comparative figures are available.

responding figures for the substantial groups of apprentices were 74.9, 86.5 and 90.3 %. The percentages—similarly obtained—of distinctions for the students from the rest of the county were 3.7, 3.2 and 7.1, whereas the corresponding figures for the apprentices were 7.1, 13.6 and 18.5%. In estimating the value of these figures, it must be borne in mind that the relative performance of the apprentices would be noticeably better if students repeating any examinations were eliminated, and that the figures are also for trade apprentices, who are not chosen with an eye to their future examination success, as well as for pupil apprentices, roughly about half of each.

Mere examination success, however, is only a part of the story—and generally an overrated one. The real test is whether or not apprentices are being selected who will subsequently make good engineers. The author is confident that the apprentices whose selection he has recommended to his management will so turn out. Already the percentage of apprentices being rejected at the end of their six months' probationary period has decreased practically to zero, while the percentage of outstanding apprentices has increased considerably.

Several comparisons have so far been made between the test scores of apprentices and their subsequent assessment in substantial groups, a total of 267 cases having been covered. Some results are shown in figure 1.

FIG. 1

RELATION OF APTITUDE TEST SCORES TO SUBSEQUENT ASSESSMENT OF 91 TRADE APPRENTICES

1.—91 trade apprentices were assessed, in the first place, in 2 groups ; consisting of :

(a) 30 trade apprentices with over 6 months' and under 2½ years' service

(b) 61 trade apprentices with over 2½ years' service.

These were then combined, an order of merit for the whole 91 thus being obtained.*

2.—The assessment was made completely independently of the author by a member of the Apprentice Supervision Department who pays frequent visits to all apprentices, teaches them and has access to all report forms, etc.

3.—The average length of time between testing and subsequent assessment was 2 years 7 months.

4.—These apprentices were assessed in separate groups as potential skilled men, the assessor being particularly asked not to let an apprentice's proficiency in classes influence his assessment except in so far as the former was likely to influence all-round proficiency at the apprentice's trade, *i.e.*, present and anticipated shops' proficiency alone was to be the basis of assessment.

(*Fig. 1 continued on next page.*)

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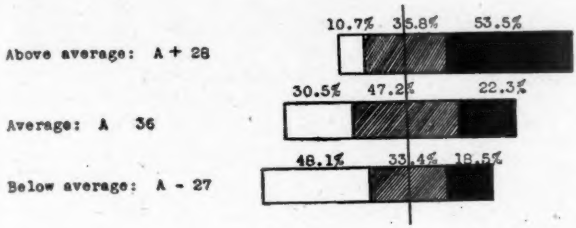
*It was thought that a rather more reliable order of merit would be obtained in this way than by ranking the whole group together in the first place.

TESTS.*



<u>Tests and Assessment.</u>

Average agreement $\frac{48.1 + 53.5}{2} = 50.8\%$

Average disagreement $\frac{10.7 + 18.5}{2} = 14.6\%$

Ratio $= \frac{50.8}{14.6} = \frac{3.5}{1}$

<u>Assessment.</u>

A + (top group) 28

A (middle group) 36

A - (lowest group) 27

A very careful assessment of 34 apprentice and ex-apprentice toolmakers, mostly of substantial experience, has recently been made by the foreman of the toolroom, after discussion with his chargehands of the provisional assessments made by them independently of one another and of him. Agreement (worked out in the same way as in Figure 1) between his assessment and the total score on four aptitude tests occurs twelve times more frequently than disagreement. The average time between testing and this assessment was 2 years 10½ months. It is interesting to observe that when 8 apprentices who have served less than 18 months in the toolroom are eliminated from the assessment, agreement (as above) occurs sixteen times more frequently than disagreement, the average period between testing and assessment for the 26 apprentices being now 3 years 6½ months. These 26 apprentices and ex-apprentices had served in the toolroom for an average of 4 years 1 month.

The value of a broad recruiting policy has been *proved* to be considerable, whilst the value of both stated interests and hobbies, and school reports has been shown to be limited. Time lost by the

* The top 28 apprentices on the total of 4 aptitude tests (ref. 9) were marked above average, and the bottom 27 below average, so as to give numerical correspondence with the assessor's groups.

apprentices has diminished very considerably and their keenness and "aliveness" generally has improved out of all recognition. The tests have also been successfully used in the selection of boys for a special scheme of training, with a view to their early entry into the drawing office, and it is probable that they will shortly be used as an aid to the more effective allocation of young boys entering the firm.

Work Done in the Armed Forces (1) of Other Countries.

The work of selecting men for, and allocating them to different duties and training courses in the Forces is the only part—although it is an important one—of the military work of the psychologist which is relevant to this article.

As soon as America entered the last war, a large co-ördinating "Committee for Psychology" was set up by the newly-formed National Research Council and to the members of this Committee is due the foundation of military psychology as a science. Intelligence testing was carried out on a vast scale and with considerable success.[21] Oral, picture, performance and written trade tests were devised, developed and applied very successfully.[22]

"In the handling of personnel in the army, the wastefulness and inefficiency of the old devices for determining trade skill and status caused such enormous inconvenience and delay that new instruments had to be devised to meet the problem."[22]

When the work of the above Committee was published, it imparted a great impetus to the practical application of psychology, especially industrial psychology, but despite the warnings of the psychologists themselves, military psychology as such was allowed to lapse.

"From 1917 onwards, however, psychological methods have been used, more or less systematically, by members of the Medical Department of the U.S. Navy for examining naval personnel; and since 1923 they have also been adopted by the Training Division of the Bureau of Navigation."[23]

"An official report declares that, as a result of the tests adopted in 1923, 'a high percentage of the unfit and inapt have been eliminated at the source, thereby saving the Navy the cost of transportation and other expenses incident to the training of recruits who would ultimately be discovered to be unfit for the service.'"[23]

The following remarks covering Japan, Hungary, Germany and Russia are taken from an article by Dr. Pryns Hopkins,[24] with the exception of one paragraph, to which a separate reference is given.

The Imperial University of Tokyo was in receipt of a generous grant from the Japanese Government in 1935 for the purpose of devising tests for the selection of aviators; and in Hungary, in 1936, when Dr. Hopkins visited the country, considerable psycho-

logical testing was being carried out in the Maria Theresa Barracks at Budapest. The passing of these tests was compulsory before commissioned rank could be obtained or before a Corporal could be promoted to the rank of Sergeant. Intelligence tests and tests of vocational aptitudes were given to select those most likely to profit by special training.

Fifteen army psychological laboratories, employing 84 highly qualified and experienced psychologists, existed in Germany in 1936. Vocational tests were compulsory for all applicants for special jobs—wireless telegraphy, signalling, flying, etc. and it was stated that 40,000 men per annum were being tested then. During the last ten years, in fact, Germany has been copying and steadily developing what America began in 1917-18.

" In particular it has been claimed that psychological tests were of special importance in building up the Luftwaffe ; and the remarkable way in which Germany, only a few years after military aviation was re-introduced, was able to organise a vast Air Force with great speed has been plausibly attributed by more than one observer to the fact that the psychological laboratories helped in selecting and sending forward the best human material from the very outset."[24]

It appears likely that Russia has been carrying on psychological testing on a substantial scale but if so, great secrecy has surrounded it and Dr. Hopkins was informed that no testing was being carried out in 1936, for the Russian Army.

The Italian Air Ministry had a consultative committee before the war and four Institutes, with headquarters in Rome, Turin, Ferrara and Naples, under the direction of a highly specialised medical corps and well-equipped for making psycho-technical examinations. " During the years 1932-1937 the regular individual examinations numbered some ten thousands a year."[25]

Dr. Emilio Mira, who had formerly been Director of the Psycho-Technical Institute of Barcelona, was appointed chief consulting psychologist to the Republican Forces during the Spanish Civil War. In a brief but interesting account of psychological work during the Spanish War,[26] he gives some account of the testing and allocation of men to different jobs in the Forces and also describes the testing and re-allocation of women, unemployed as a consequence of the collapse of the textile industry. The following is the conclusion of this eminent psychologist : " Generally, it is possible to say that the results obtained during the Spanish War by a very small band of trained psychologists, working under the worst imaginable conditions, do definitely suggest that the thorough application of psycho-technical principles would be of very great use in the event of another war."

In an account of the *Personnel System in the American Army*,[27] the development of the most useful forms and questionnaires and

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the keeping of systematic and comprehensive records is mentioned (a field, by the way, in which the vocational psychologist can make a further, and has already made a considerable contribution). It is also stated that "tests are given, first to determine whether the picture so far is a true one, whether the man is indeed qualified along the lines indicated by the interview; and, second, to delve further into his skills and abilities and discover latent talents and deficiencies." Oral trade tests are given, as well as intelligence tests and tests of mechanical aptitude, etc. "After being classified and outfitted at a reception centre, the soldier goes to a replacement training centre for thirteen weeks' basic training."[27] (*c.f.* our General Service Corps mentioned below.)

"The Personnel Research Section of the Personnel Bureau of the Adjutant-General's Office is charged with responsibility for developing aids for use in classifying officers and men with respect to their abilities and skills, educational background, civilian and military experience, intellectual capacity, personal qualifications, special aptitudes and indicated best Army usefulness."[27]

"With the help of occupational analysts in the Social Security Board, fresh job descriptions of many important Army occupations have been prepared and standardised oral trade tests made available to interviewers at Reception Centres."[27]

Work Done in the Armed Forces (2) of Britain.

The establishment of the Directorate of Selection of Personnel* in the British Army (in June, 1941), had been strongly urged by an advisory committee of three psychologists (Professors Burt and Drever, and Dr. C. S. Myers, Hon. Scientific Adviser and lately Director of the National Institute of Industrial Psychology), appointed by the Adjutant-General; the three Senior Officers in it are all ex-National Institute of Industrial Psychology staff psychologists. The public press of May 29, 1942, quoted the Adjutant-General as saying that a complete job-analysis of the whole British Army had been carried out, and at about the same time the General Service Corps was created. The Committee on Skilled Men in the Forces had previously stated in its second report[28] that the main change required in the technical training of the Army was a better selection of trainees.

The selection had previously been carried out by interview. There are a very large number of jobs in the British Army and therefore, through no fault of their own, it is probable that the Selection Officers were often quite ignorant of many of the jobs for which men were required. The limitations of the method

* Since this was written a short history of the Directorate of Selection of Personnel has been written by Dr. Myers—"The Selection of Army Personnel": *Occupational Psychology*: Vol. xvii, p. 1-5, January, 1943.

are obvious (but the position is not radically different from that obtaining in the Employment Office of a large firm). In addition, it must be borne in mind that the demands of the Army for men for jobs of an engineering nature must obviously exceed the number of recruits who have had engineering experience (which is the position also in the other Forces and in industry). The problem therefore arises of picking out from those who have had no engineering experience men best fitted to be rapidly trained for engineering occupations. Intelligence and aptitude tests are being used—none too soon—for this purpose. During the six weeks each man spends at his primary training centre, a good deal of relevant information is collected on him and as a result of this and of the man's various test scores, the Personnel Selection Officer states first, second and third recommendations in terms of a limited number of categories of jobs. An attempt is then made to fit supply to demand on the basis of first recommendations, as far as possible.

Suitable records, supplemented from time to time by reports on the man after he has been allocated, are being kept, and no doubt valuable and interesting information will accrue from this large-scale "follow-up."

Mr. Alec Rodger (who had previously been seconded to the War Office for experimental work in the use of selection tests in the Army) also took part, early in 1941, in "a survey conducted by the Admiralty, the aim of which was to advise the Second Sea Lord on the scope for the application of psychological methods to the initial recruitment of men for the Royal Navy and to their subsequent allocation. Consequent upon this survey, the Admiralty requested the Institute* to provide the services of several members of its staff for personnel selection work".[29] The Head of the institute's Vocational Guidance Department—Mr. Rodger—was appointed Senior Psychologist to the Admiralty, with the full-time assistance of five other members of the Institute's technical staff. Considerable testing is carried out in the Royal Navy, intelligence and aptitude tests being used. It will be appreciated that there are a certain number of highly skilled trades in the Navy, such as radio and electrical mechanic, and that it is very necessary to be able to recommend men for training courses for them who are likely to "make the grade" and turn out successfully.

The Royal Air Force also employs psychological tests to assist in more efficient allocation. The Central Trade Test Board—the governing body regarding allocation of personnel to trades, or for training in trades—has on its establishment a psychologist and a number of personnel specially trained by him as Personnel Selectors.

* The National Institute of Industrial Psychology.

Psychological Tests in Industry.

Despite both the appalling wastage and the immense possibilities in British industry, comparatively little has been done in it, and considerably less by it on the application of more systematic methods to the selection and allocation of workers. The staff investigators of the National Institute of Industrial Psychology have assisted a number of firms by devising selection tests of one sort or another, and training their personnel in giving them and interpreting scores on them. General accounts of the problems covered by some of these investigations appear from time to time in the Journal of the National Institute of Industrial Psychology—*Occupational Psychology*—for example, one recently appeared[1] dealing among other things, with the selection of inspectors, a matter that should be of some topical interest. But as the work carried out for firms by that Institute is confidential, no further mention of it may be made here and as far as I am aware, no account has been published of any extensive and systematic selection and allocation carried out by a member of a British engineering firm in his firm. Two very brief accounts have appeared in *Engineering Bulletin* recently,[30 31] of the work in progress in engineering firms,

Mr. B. Seebohm Rowntree writes :[32] "After nearly sixteen years' experience of vocational selection, I am in a position to say that it has completely justified itself. It has reduced the number of misfits and the time taken to train selected workers." Two other writers state :[33] "The experience of a firm where the jobs were very varied in character and as varied in physical and other requirements proves what can be done with scientific selection and scientific training, the wastage in selection, *i.e.*, the misfits, were reduced by over 75%, and the time and cost of training were reduced from twelve or eighteen months to three and a half and from £30 to £5."

The De Havilland Aircraft Company, Ltd., High Duty Alloys, Ltd., Mather & Platt, Ltd., and Saunders-Roe, Ltd. are some British engineering firms now using psychological tests, and there is evidence that many other firms are envisaging the possibility of doing so. Certain other firms have been using tests with great success for some time, *e.g.*, Imperial Chemical Industries, Ltd., Dyestufls Groups,[34] and I am informed that it is the intention of the G.E.C. Osram Lamp Works almost immediately to revive testing.

In a very brief article published in 1929[35] some interesting information is given as a result of the (then) six years' experience of the well-known Philips' Electric Lamp Works at Eindhoven, Holland, with psychological tests. This firm then employed 17,500 people. Workers in the diamond-piercing department underwent from 1 to 2 years' training, which cost the firm on an

average, £250 per head. They were all recruited from the ordinary factory staff, but whereas before the introduction of psychological selection tests 50% of them were found to be incompetent, after the introduction of the tests this percentage fell to 12½%. Tests for admission to the Trade School reduced the percentage of unsatisfactory pupils in the beginners' class from 17 to 4. Two boys who failed to pass the tests but were admitted by way of experiment failed also to complete the course. A scholarship fund existed for the children of the factory workers. When the usual examination was supplemented by intelligence tests a marked reduction occurred in the number of scholarship holders who afterwards proved unsuccessful. Four assistants in the physics laboratory, out of 16, were judged unfit for their work. The tests had distinguished three of these. It is interesting, in view of the later American work mentioned below, to notice that at Messrs. Philips' factory, highly satisfactory results were obtained in the selection of foremen and assistant-foremen, and also in the grouping of workers for various kinds of instruction into classes which were more homogeneous intellectually. It is, of course, much easier to instruct a class of this nature than one the members of which are heterogeneous intellectually—some very quick on the uptake and generally bright, some slow to get the point and generally dull.

Dr. J. L. Prak, the firm's psychologist, stated that after working for 7 years with tested personnel, he still found the test score the most reliable key to their personality he possessed.

American Work.

In 1937, the Lockheed Aircraft Corporation found that hardly two out of three new employees developed into satisfactory workers and came to the conclusion, after investigation, that 80% of individual failures, *i.e.*, employee misfits, was due to temperamental faults and maladjustment. To supplement the routine employment office procedure, a testing programme was initiated, in order to eliminate unsuitable or inapt applicants and to allocate suitable ones most effectively within the organisation. This has been carried out on a large scale and nearly 300,000 applicants have been tested. Lockheed looked for four major points :[6] a well-balanced temperament, aptitude for a particular job, special knowledge or skill, and intelligence, Qualified applicants are given a test of mental ability—an intelligence test—and the Humm-Wadsworth Temperament Scale. This consists of 318 questions requiring "Yes" or "No" replies, from which information is obtained on certain fundamental components of temperament ; this is then recorded on a "Profile" or Psychograph, which gives a visual picture of a man's temperamental assets and liabilities.

Two mechanical aptitude tests are used and, in addition, Lockheed

has devised and standardised five clerical aptitude tests—the Lockheed Clerical Test, Typing, Clerical-Typing, Stenographic and Filing, and also a number of trade tests—Accounting, Blueprint Reading, Drafting, Final Assembly, Lofting, Machinist, Pattern Maker, Precision Assembly, Sheet-Metal Assembler, Sheet-Metal Worker and Template Maker, etc. The mechanical aptitude tests are given because it was found that applicants with poor mechanical aptitude required several times the training that those did with good mechanical aptitude ; and the intelligence test is given to avoid the obvious mistake of placing an exceptionally intelligent individual in a routine, monotonous job, on which he will soon become "stale" and dissatisfied. "Certain jobs demand men whose intelligence falls within a given bracket. Some applicants are too smart for certain jobs ; others do not have sufficient mental alacrity. . . "* The trade tests are of two types—written tests of trade knowledge, and manual tests such as actually rivetting plates together, laying out sheet metal problems, etc.—and scores on them are weighed with an applicant's experience, so that he may be placed as a learner, junior, senior, etc. or eliminated as a trade bluffer. The mechanical aptitude tests are of particular importance now that the employemnt market has been almost entirely drained of men with aircraft experience and it is necessary to bring in men with allied experience who will become proficient with a minimum of training.

The Personnel Department use tests not only as important supplementary aids to pre-selection, but for re-evaluation of present employees. Misfits are tested, the results diagnosed and terminations or corrective procedure suggested. Men of unusual promise are tested and supervisors picked ; in fact, Lockheed reports that : "One of the key advantages of testing is its ability to select leaders and supervisors. . . ." Men are also selected for training schemes who have every prospect of completing these really satisfactorily. "The Company seldom employs a man or woman even in executive capacity without first giving the tests," and reports that "nearly every time an applicant has been employed in spite of adverse test results, the Company has regretted it."

In the face of national emergency, Lockheed has had to fill many jobs with applicants whom it would not normally have accepted. Two out of every three workers who had to be dismissed in 1941 had shown adverse test results. Yet Lockheed's turnover is substan-

* While some of the information given here relating to the Lockheed & Vega Aircraft Corporations was obtained from the articles referred to in this article (refs. 6 and 36), I am indebted to the kindness of Mr. Jack Fowle of the Employee Service Division of Lockheeds for further recent information, including a pamphlet entitled : *Testing Program of the Lockheed and Vega Aircraft Corporations*, from which this is a quotation.

ially less than the industry average. Apt and adjusted employees increase production and readily adapt themselves to the pressure of the present emergency and Lockheed's production per man is well above that for the industry. Morale has been kept at a high pitch and training costs per man decreased.

"With our crying demand for men," writes George H. Prudden, Works Manager of the Vega Airplane Company, a subsidiary of the Lockheed Aircraft Corporation, "we sometimes substitute 'wishful thinking' for sound analysis of material in hand. It seldom works." He adds: "I put great store by these tests although sometimes they get in our way, so to speak. We need men badly, and it is exceedingly disappointing to lose men through the test. But I have never had the test fail me yet. You can take some of those borderline cases that are wavering, and do a good deal with them; but when you get extreme cases you will come a cropper every time trying to fight them."[36] His Company had a "Union Shop" but this had no objection at all to these tests. It had seen the efficacy of them and believed in them as the Company did.

R. G. LeTourneau, Inc., have used psychological tests for some years. They realised the importance of a good application form for applicants and studied experimentally the value of 100 such forms then used by other firms. I mention this point because it emphasises the general impression I get from a careful study of a number of American articles—that many American firms realise the hopeless inadequacy of the usual employment and personnel methods and are willing to learn—the more progressive the firm the more it realises it has got much to learn.

LeTourneau have worked on selecting inspectors, welders, machinist apprentices, pressmen, setters, and supervisory trainees, and, like other firms have used, among others, mechanical aptitude tests. "Mechanical ability, which plays an important part in many of our jobs, can be definitely determined by tests. We know this because we have tested more then 1000 men and, later have watched them progress on many jobs. Those who received low grades on the mechanical aptitude test have failed miserably in the plant; those receiving high grades have advanced time and again."[37]

An interesting case is described in the article just referred to, of an assembly mechanic supervisor, sceptical of the value of tests. He was finally persuaded to take the mechanical aptitude test and received a grade of 99 in 50% of the allotted time. His 30 men were tested; all received grades of 90 except 3, who made very low grades. "When told these test results the supervisor said he could name the three low scorers, and he did. They were trainees who had been having considerable difficulty for at least four months. They had cost the company their wages and a goodly part of an instructor's wages, and I am convinced they would never have

made assembly mechanics. Soon after, at the request of this supervisor, the three men were transferred to other work where two of them are advancing well. The supervisor ruled that henceforth no one could work in his department unless he had a passing grade on the mechanical aptitude test."

In emphasising the value of dexterity tests for selection for small bench assembly work, the author of the article just referred to, who is Industrial Relations Manager at R. G. LeTourneau, Inc., gives an interesting illustration of a radio-tube plant where nine out of ten girls who did well on certain dexterity tests met assembly production requirements within 2 weeks, whereas only 30% of the new employees who did badly on the tests succeeded in a month. " In addition, this company reduced its monthly turnover rate on 500 girls from 15 per cent to approximately 2 per cent through the use of better selection procedures, alone. Can you imagine," the author asks, " training a whole new force every seven months—well, that is exactly what this company had been doing before the analysis of their exits."

LeTourneau, like Lockheed, has paid a good deal of attention in their selection procedures to the assessment of temperamental factors of occupational significance—particularly to sociability, stability and confidence. The company has followed the progress of many men who have started out with negative grades on confidence or stability. In 90% of the cases they found the low-confidence man slow to advance and the low-stability man wanting to change his job or leave in a few months.

Trade tests have been developed for welders and are being used for purposes of classification, and for purposes of upgrading on the basis of skill. Similar tests for blueprint reading are in use and tests for machinists are being worked out. The importance of work of this nature can hardly be over-estimated. The increased incentive to work well of an employee who knows that his skill and knowledge will be fairly and objectively measured periodically, with a view to his being considered for promotion and/or for an increase in pay must be considerable. One of the greatest potential uses in industry of tests of all kinds is in connection with the evaluation of employees, but any such evaluation would have to be made slowly, on the sure basis of gradually proven results and of the co-operation of the employees' representatives. Not only is it unlikely that the latter would raise objections, but, if the work were introduced tactfully there is every reason to suppose that their active co-operation would be forthcoming.

The turnover rate at LeTourneau has been reduced from 10% to 5% and as a result at least 50 fewer men per month have had to be trained in each plant. Failures in the apprentice welding school, which were quite common in the past, seldom occur now.

Many of the foremen have, without solicitation, expressed their appreciation of the better type of men the personnel department is sending them. The newer supervisors chosen by these selection methods are showing up well and training and upgrading have taken a big step forward.

An article of considerable interest[38] by Dr. D. W. Cook, who has, for the past seven years, been in charge of psychological testing, test research, and test development and standardization at the Western Electric Company, Kearny, N.J., describes how his company, which has been utilizing psychological tests for over a decade, has devised and applied tests, particularly in selection for unskilled jobs. This is a field in which tests may be particularly valuable, as the aptitudes or abilities to be assessed (such as eye and hand co-ordination, extremely rapid manipulative ability, etc.) are few in number, may readily be measured by simple standardised dexterity tests, and cannot, in fact, be measured satisfactorily by any other means. In view of the increasing ratio of unskilled or semi-skilled to skilled jobs, it looks as if this is a field in which considerably more research will be carried out.

Dr. Cook names the nine factors eventually included in the analysis made of the jobs in his company and the steps to be taken in "validating" a test. He also gives some extremely interesting results obtained from tests used for selecting solderers, relay adjusters, cable formers, testers and inspectors, and junior draughtsmen. Incidentally, as evidence of the unreliability of the interview, he cites a well known early investigation by Hollingworth, in which 57 applicants for sales positions were interviewed and ranked from best to poorest by twelve experienced sales managers, responsible for selecting salesmen. Each interviewer used the methods to which he was accustomed. There was no agreement between the orders of merit, and one case was ranked No. 1 by one judge and No. 57 by another. Later investigations corrobate these findings.

The Procter and Gamble Company also utilises general intelligence and mechanical aptitude tests as part of its regular employment procedure and uses rating-scales for the periodical assessment of its workers, not by one person, but by several.[39] Those consistently receiving high ratings are considered for promotion when foremanship vacancies occur. In connection with selection for the latter, it may be pointed out that psychological tests have a place, as well as questions designed to measure the amount of company information each man had acquired. I have no doubt that tests, as well as other systematic employee-evaluation, could assist very considerably in enabling likely men to be brought to the notice of the company management for a final selection to be made for positions as foremen or chargehands or supervisors, a point of some topical

importance, as the dispersal of industry in England has meant that frequently anything from ten to thirty foremen are required where one was sufficient before, and courses on foremanship have been arranged by the Ministry of Labour and National Service in conjunction with the Board of Education and the Scottish Education Department.

Dr. Charles A. Drake, Consulting Psychologist to the Johnson and Johnson Company, New Brunswick, N.J., describes[40] the use of "specially-designed performance tests" in the company. (He also criticises pencil-and-paper tests, but it seems to me that the unwarrantable use he appears to have made of them is more deserving of criticism than the tests themselves). Twenty-two tests for industrial use were designed and tried out on substantial numbers of applicants and employees, as a result of which the following abilities (which were sub-divided further) were isolated and identified:

(1) General finger, hand, wrist, arm dexterity; (2) Dual hand dexterity; (3) Bilateral hand dexterity; (4) Hand and foot co-ordination; (5) Machine tending ability; (6) Inspection ability.

Dr. Drake does not advise selection by the aid of tests unless it appears that this will pay. His company has proved that it will.

Guy W. Wadsworth, Jr., joint author of the well-known Humm-Wadsworth Temperament scale already referred to, describing the place of "Personality in the Personnel Program"[8] gives some results from a recent survey of 814 cases of employees whose performance and behaviour on the job were reported on from year to year since 1934. Mr. Wadsworth is the Personnel Manager of the Southern California Gas Company and Southern Counties Gas Company of California and "has had over ten years' experience in using tests of mental ability, aptitude and temperament in the selection and placement of workers for the Pacific Lighting Companies on the West Coast."

"The records," he writes, "were checked by one section of the staff for supervisor comment regarding (a) all-round success, and (b) "personality" (favorable or unfavorable) for the work. Where the employee was rated as a "success" on the job, and as of pleasing or acceptable personality by his supervisor, the record was marked "Plus." Where the employee was less than satisfactory in his work, or rated as "difficult" or unsatisfactory from the viewpoint of personality, the record was marked "Minus."

"The testing staff in one of our other companies checked personality tests which had been completed by the same employees," and the temperament findings were assessed "Plus" or "Minus."

"In 77 per cent of the cases, "Pluses" and "Minuses" on the job agreed with "Pluses" and "Minuses" in the test results."

Mr. Wadsworth concludes that his work on temperament assessment has been well worth while. "According to individual reports

returned annually since 1934 by our supervisors, less than one hiring in ten has proved unsatisfactory, while 60% more hirings turn out to be superior than was the case with non-test methods." He adds, however, that these results are not attributable to temperament testing alone, although applicants had to make an acceptable showing in this as well as in the other tests used. My own view is that whilst every attempt should be made to improve the technique of the interview by the introduction of simple scientific procedures (the value of which is well-known to industrial psychologists), attempts at more elaborate assessment of temperament would, at this stage be premature—in British industry, that is. They would necessitate the services of an expert in this specialised field, and in my view there are other and more pressing needs in the field of industrial psychological testing—and more important problems, which, it is certain, can be solved more readily.

Many other large American firms have been successfully using psychological tests—the Scovil Manufacturing Company, the Aluminium Company of America, the General Electric Company, Eastman Kodak, the Philadelphia Electric Company, the Milwaukee Electric Railway and Light Company, and the Sperry Gyroscope Company—to mention but a few. I was recently informed that over 200 firms are taking advantage of the services rendered by Dr. Humm (the Doncaster G. Humm Personnel Service, Los Angeles, California), so the total number of American firms using tests of various kinds must be considerable. A number have been using them for years.

Occupational Analysis.

Industrial, or as they are more appropriately called, occupational psychologists have, for years, urged the necessity for more detailed information being made available concerning different jobs—information of all sorts, *e.g.*, methods and conditions of entry, pay, hours and conditions of work, prospects, etc., and descriptions of the materials, tools and processes used. A careful description of just what the job involves and of what qualities of physique, what level of intelligence and what aptitudes are necessary for success in it, they have stated, time and time again, are essential for the proper application of the considerable body of relevant psychological knowledge to the problems of vocational guidance and selection. The National Institute of Industrial Psychology report No. 1,[41] dated 1926, dealt with this topic, and the investigators of that body regularly carry out analyses of jobs as a preliminary to the introduction of selection tests for them. No work of this character has been carried out in England on a large scale and it is for this reason that I propose to devote some space to an account of the *official* work carried out in this most important field by the Occupational Analysis Section of the Bureau of Employment Security, Social

Security Board, United States of America. For this, I am indebted to an article[42] by its chief, Dr. C. L. Shartle. I may, however, point out that the American firms whose work in the field of scientific selection I have mentioned above, themselves stress the necessity for adequate job analysis, Dr. Cook, for example, pointing out that after his company had done a good deal of preliminary work, "it was decided that a careful job analysis, in which the job would be studied in detail and described in terms of abilities and skills which could be objectively measured would be the basis of all future test work,"[38]

The responsibility of the Occupational Analysis Section of the United States Employment Service Division consists of developing occupational information, occupational classification and employment testing materials. It gives technical assistance to affiliated State Employment Services in the use of these occupational research materials, acts as consultant, in effect accepts responsibility for the training of workers in the personnel field, and acts as a general clearinghouse on job analysis and selection methods. Many employers are being referred to it for help on their problems by the Defense Commission, and it has, as a matter of fact, stimulated the use and development of improved selection methods generally. It deals with a large number of enquiries both from employment offices and from employers.

During the past few years, the Occupational Analysis Section, with the help of three outstanding private foundations and the guidance of a Technical Board nominated by the National Research Council and the Social Service Research Council, has carried out occupational analysis on a large scale. Extensive job information has been collected, and a large number of improved selection techniques developed, in conjunction with thousands of employers and thousands of workers. Trained job analysts, working in several research centres, have analysed jobs in practically all the industries in the United States. In order to get representative samples of a job, it is analysed in several parts of the country. The 60,000 jobs so far (1941) analysed break down into 18,000 separate jobs.

The *Dictionary of Occupational Titles* was published in the Spring of 1940. Volume I defines 18,000 job titles and classifies over 30,000; it consists of 1,200 pages. Volume II contains the classification structure of jobs and it is possible, conveniently, to find in it related jobs and thus consider possibilities of transfer of skill—a vitally important point now that the labour market has been drained of men with experience of jobs essential to the country's war production. To quote Dr. Shartle: "This *Dictionary of Occupational Titles* which represents for the first time in America a listing of jobs, definitions, and classifications, has been widely adopted as a standard in the defense program. The Army and Navy and the

Draft Boards are using it. In fact, the Occupational Analysis Section is now studying the jobs in the United States Army. We are making 7,000 job analyses and there probably will be about 4,000 distinct jobs or occupations. On the basis of the job analyses we have completed thus far, we estimate that about one-half of these jobs are closely related to jobs in industry. As fast as these jobs are analyzed, they are being classified according to the dictionary scheme so that it is possible to observe first-hand the relationship of industry to Army jobs. You can see how useful these analyses are to the Army in making assignments and how helpful such materials will be in placing persons with Army experience in related industrial jobs."

Public employment offices throughout the country use the standard dictionary terminology and classification, and from their files they can very easily and quickly discover related jobs. The use of code numbers instead of job titles, in firms, facilitates accounting procedures by the use of punch cards.

The Occupational Analysis Section gives assistance to State Employment Services in training their personnel in job analysis methods. "It has been found," Dr. Shartle writes, "that by having trained job analysts in the local offices it is possible to obtain more complete information from employers as to their hiring requirements and also to obtain more complete information from applicants. A person who has had job analysis training, even though that job analysis training is brief, finds out for the first time what that job really is. Our experience indicates that those employment enterviewers who have had training in job analysis do a better job of interviewing, a better job of recording significant occupational information, and also do a better job in interpreting worker qualifications in terms of job requirements. I strongly recommend job analysis training for persons who do employment interviewing. Employment Service interviewers all over the country are rapidly being trained in job analysis, and in one state every interviewer who is concerned with placement is a trained job analyst."

The Occupational Analysis Section has been carrying out a long-range research programme in the use of aptitude tests for occupations for which trainees are frequently requested or which beginners may enter. So far (1941) 150 samples of workers have been studied throughout the country in 80 different occupations and work is now being done on such jobs as those of the machinist apprentice, airplane mechanic apprentice, aircraft assembler, aircraft rivetter, radio assembler. Aptitude tests, scientifically sound, and standardized for a specific job, are now (1941) in use in 137 public employment offices. "Tested applicants are now being referred by the thousands.

As many as 3,000 tested learners are being referred to a single plant." In connection with these tests, Dr. Shartle gives a timely warning that it is not possible to tell whether a test is predictive for a given occupation merely by inspection. He also mentions that one of the greatest difficulties in standardising tests is to discover a good index of proficiency against which the tests can be validated or checked—a point that anyone with experience of work of this nature in industry can well understand.

Trade Tests.

The Occupational Analysis Section has developed oral trade tests (or oral trade questions, as they are sometimes called) for over 130 occupations—with the help of 6,000 employers and 20,000 workers. The American Army and Navy use them, as well as Public Employment Offices and the Occupational Analysis Section has given considerable assistance to the Armed Forces in their use. They can be given as part of the regular interview, in from three to eight minutes, and for a skilled trade are used to differentiate three groups—experts, apprentices and trainees, and novices.

Guy B. Arthur, Jr. comments upon the favourable reputations which the state and federal employment offices are gaining, and attributes this partly to their extensive use of trade tests.

J. C. Chapman, in his book, *Trade Tests*,[22] which is, I imagine, the most readable and lucid, as well as the most authoritative book on the subject, gives an account of the techniques developed in the American Army in the last war for assessing trade skill.

Trade tests, as is well known, have been used by the British Army and Navy for years, but these are of a performance nature and I doubt whether one engineer in a hundred in England realises that it is feasible to measure trade skill in any other way, let alone realises that it was done extremely successfully and on a large scale some 25 years ago.

Some very brief description of the work done in the American Army on trade tests is given here because the problem which the Army faced is little different in essence from that generally faced by industry. The American Army, transporting, as it did, to France, men who alleged they were skilled, was early forced to realise the wastefulness and inadequacy of the old devices for assessing trade skill and status, and was likewise forced to devise new instruments to meet the problem.

The essential demands of the Army were that the methods for the assessment of trade skill must be applicable to all trades, adequately usable by an intelligent examiner who has no personal knowledge of the trade, must yield a rating of a man independent of the examiner's individual judgment, and must be rapid and in

most cases not require the use of tools or apparatus. The methods developed were oral, picture, performance and written trade tests.

Oral trade tests are only applicable to skilled trades, where certain knowledge or information is required as well as manual skill in performing certain operations. The assumption that oral trade tests can be made depends upon the complexity of the job—on the extent to which trade knowledge and information is necessary for its successful performance. No doubt the great body of British industrial opinion would be extremely sceptical of such tests, alleging that many, perhaps most, skilled men can do a job but cannot answer questions on it. This article, however, is concerned with facts, and with opinions only to the extent that they are substantiated by facts. In this case, the facts are clear and they are clearly stated by Dr. Chapman. The results of the oral tests tried out on hundreds of thousands of men showed that such individuals virtually do not exist. Experiment and experience showed that the oral tests were very successful in differentiating four types: (1) novice; (2) apprentice; (3) journeyman; (4) expert. They made short shift of the bluffer.

The general procedure in devising the tests was to formulate a substantial number of questions, with the help of foremen and skilled men, and trade journals, magazines and textbooks. These questions were to be such that they were likely to be answered correctly only by the trade expert and they covered a wide field of the relevant trade. They were tried out in different localities, so as to eliminate questions having local significance only and so that the wording of the questions might be modified, if necessary, and, finally, various modifications having been introduced, to test whether or not trade skill could be inferred with a fairly high degree of accuracy from trade knowledge, *i.e.*, to find whether or not the expert could answer all or most of the questions in the test correctly, the journeyman less, the apprentice less still, and the novice or worker in an allied trade none or very few. The fundamental assumption in oral trade tests is that the knowledge which the test assesses is only acquired in the course of learning the trade, and therefore, that the extent to which a man can answer the questions correctly is a measure of the extent to which he has acquired trade skill.

Devising these tests is a very skilled job, about which nothing can be said here, except that experience showed that the single-answer question was the best. A question such as: "How should a spring be removed from a car?" is a bad question, because it can be answered in a large number of ways and the answers cannot be assessed objectively by an interviewer—however intelligent—who is ignorant of the trade of motor mechanic. Questions should be framed with regard to the essential element of a whole process,

so that the answer is a key-word (or one of a very few key-words) or a short sentence involving that key-word. Chapman gives many interesting examples of oral tests and readers who are interested in acquiring further information on these, and on the three other types of tests developed, are referred to his excellent book.

The Future of Selection Tests.

It is fashionable, nowadays, to express pious hopes for the future in many spheres. The sceptic, however, may be permitted to raise his unpopular voice to the extent of pointing out that whilst the expression of views is one thing, the possession of power, or, to put it more bluntly, cash (for this is what it amounts to), to implement these is quite another. The industrial psychologist will probably be the last person who will be consulted if the question is under discussion of any large-scale policy relating to industrial psychology.

I consider that it is improbable that any development on scientific selection will be made in this country on a national scale in any way comparable with, *e.g.*, the foundation of the Occupational Analysis Section of the United States Employment Division, though the benefits which would accrue from such a development would be enormous.

Industrial psychology can at present be taken as a separate subject in engineering examinations in only one University—Glasgow—where it features among the optional subjects for the B.Sc. (Hons.) degree in mechanical and electrical engineering, and it has been taught as a separate subject in only one English technical college—that of the County of Staffordshire. Certain aspects of the study of the " human factor " already feature in the examinations of certain engineering institutions for their (Associate Membership or Graduateship), and as a subject for endorsement on the Higher National Certificate. The progressive Institution of Production Engineers explicitly states in the preamble to the syllabus for its Graduateship examination : " The Council of the Institution feel that although one of the major problems of Production Engineering is that of the human factor . ... too little attention has been given to this important subject in the curriculae of Technical Schools."

Regarding vocational selection, my own experience of senior apprentices taking the Higher National Certificate and endorsement courses, in which reference is made to it, is that almost without exception they are extremely interested, but that the subject is all too frequently dealt with in a very scrappy manner. No doubt this is chiefly because the subject is regarded as " new-fangled " and because there is, in this country, very little literature of an engineering nature dealing with it.

There is already decisive evidence of the value of intelligence and vocational tests in the selection of boys, both for the engineering industry and for schools giving a biassed education in preparation for an engineering career, and use is being made of them by several education authorities. There is, however, plenty of scope in engineering education for their further use, in, *e.g.*, Universities and technical colleges, for aiding and advising students as to the type of course they should follow.

The slight facilities existing in this country for training personnel in basic psychology, occupational analysis, the use of psychological tests and the interpretation of test-scores are, of course, one of the most serious drawbacks with which any progressive industrialist, contemplating the use of tests, is faced. There is no official clearing-house of information in this country, as there is in America, the place of an official body having been taken unofficially by the National Institute of Industrial Psychology, which has been, until fairly recently, under the direction of that Grand Old Man of Industrial Psychology, Dr. C. S. Myers, who has done more to inspire and direct the growth of his science than any other man in this country, and remains Honorary Scientific Adviser to the National Institute of Industrial Psychology. This body, which is not run for profit, has conducted short courses for Employment Managers on the technique of applying tests, and I am informed that it hopes, after the war, to extend its activities of this sort. But valuable though this is, it can do little or nothing directly to advance investigation into the basic problems of vocational selection.

It is, therefore, to be hoped that this body will be given greater facilities, for further research, and that it will be put on an official basis, or, alternatively, that an official body will be erected (under the aegis of the Ministry of Labour and National Service ?) which will assume as one of its major duties research into tests for vocational selection and guidance, and the compilation of data from extensive occupational analyses. Greater encouragement ought also to be given to University psychological departments to extend their research into problems of selection in industry and commerce.

In the engineering industry, there is a tremendous field for the development of systematic selection methods, but really substantial progress will only be made when it is realised that this is a problem comparable in importance with other important and industrial problems, such as those of design, planning, and management. The chief buyer and the chief inspector of inanimate material are already highly paid employees ; there is much room, not to mention much need, for raising the status of the Employment Manager, the man concerned with engaging the most important material of all—the human material.

Conclusion.

In the course of this brief survey, I have attempted to give the engineer reader some idea—from my own experience and from my all too scrappy and fragmentary reading—of where and how and with what purpose and results selection tests have been used. It may be as well to end on a note of warning, admirably stated by Dr. Pond,[37] who is in charge of all testing work for the Scovil Manufacturing Company ; and on which programme she has worked for twenty years :

" If we try to place all the responsibility for the maintenance of a good working force on one instrument, we are going to be disappointed. Testing, to be successful, must be integrated with good interviewing, good job analysis, good training, good supervision, good personnel evaluation, and with opportunities for personal progress and growth in the organization as a whole.

" Second, let us assume when we speak of the values of a testing program that we mean a good program based upon a careful investigation of the factors which influence success or failure in any occupation. These may be factors of skill, of education, or of the basic ability to acquire education or skill, or they may be factors of attitude, or of the whole group of responses of an individual which we call personality. Any good testing program must be based on a realization that these factors influence success in different degrees in different occupations, and that some of them are roughly measurable, and some are not."

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Industrial Psychology in Practice, Miles and Welsh ; *Industrial Psychology,* edited by C. S. Myers ; and *Industrial Psychology in Great Britain,* C. S. Myers ; all of which deal among other things, with selection. Also, *Mechanical Aptitude,* Cox ; " Measurement of Mechanical Aptitude," Schultz—*The Machinist,* December 13, 1941 ; and *Enquiry into Conditions of Employment of Ex-Secondary School Boys*—a most illuminating pamphlet (price 1d.) published by The Rotary Club of Balham.

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My cordial thanks are also due to the authorities of Princeton University, New Jersey, who very kindly sent me a selected, annotated bibliography of *Employment Tests in Industry and Business,* as a result of which several interesting publications were brought to my notice, including those of the American Management Association. These were very kindly loaned to me by The Management Library, 1, Doughty Street, London, W.C.1., to whom my thanks are also due.

Research Department: Production Engineering Abstracts

(Edited by the Director of Research)

NOTE.—*The addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough.*

ANNEALING, CASEHARDENING, QUENCHING.

The Case-hardening of Steel. (*Machinery, February 11, 1943, Vol. 62, No. 1583, p. 152, 3 figs.*).

The process of carburizing. Choice of steel. A typical heat-treatment process. The tempering process. Selective hardening. Copper plating. Thickness of plating. Different carbon-gradients produced in the same steel by different carburizing compounds. Case gradient. Required depth of case. Nitriding. Typical nitriding process.

Influence of Delayed Quenching During Solution Test Treatment on the Resistance of Dural to Intercrystalline Corrosion. ((*J. C. Arrowsmith and G. Murray. Sheet Metal Industry, Vol. 16, No. 188, December, 1942, p. 1879*).

The effect of varying the delay period between removing duralumin from the heating furnace and quenching in water has been studied with particular reference to the corrosion resistance of the product. It has been established that this delay should be not more than 10 sec. if a high degree of resistance to intercrystalline corrosion is to be ensured in thin gauge metal.

Coastal atmospheric corrosion tests on duralumin-type alloys, which were protected by various types of surface treatment have been carried out. These demonstrate that accelerated corrosion tests on the bare metal should not be regarded as sure indication of the ability of a material to withstand service conditions. In particular, it is shown that the resistance of the core of aluminium-coated aluminium alloy to intercrystalline corrosion is of only minor significance in determining the behaviour of the composite material.

(*Communicated by D.S.R. Ministry of Aircraft Production.*)

EMPLOYEES, WORKMEN, WOMEN, APPRENTICES.

The Status of the Foreman. (*Industrial Welfare, January, February, 1943, Vol. XXV, No. 286, p. 5*).

The war has given prominence to the position of the foreman in industry. Engagement of labour : The foreman is the best judge of the labour he requires for the actual job in his own department and he should be consulted. Priveleges : (a) those which put them on a similar or equal footing with office staff, (b) special privileges related to their own job. Information on policy : Workers say that the man who should be consulted about what they think, how they feel, what they like and do not like, is their immediate supervisor, the " boss " on the firing line.

Experience has proved that the best method of keeping foremen well informed is through regular or occasional conferences. The foremen's council:

Inter-works foremen's conferences are a development which has great possibilities. A definite line of promotion helps to emphasise the status of foremanship. Leading hand, junior chargehand, senior chargehand, assistant foreman. The possibility of promotion to positions above foremanship may be a useful incentive. It is worth considering whether managements should henceforth require a definite standard of general education and technical qualifications for foremen.

Trends in Employment Procedures, by Paul S. Achilles. (*Personnel, U.S.A., January, 1943, Vol. 19, No. 4, p. 609*).

How much does it cost to hire a worker, and how long does each step in the employment procedure usually take? With hiring going on at a rapid rate, have many personnel departments found it necessary to modify their procedures? How extensively is testing being employed? The author sent a questionnaire covering these points to members of the A.M.A. Personnel Division, and in this article he describes the trends indicated by the answers and shows how the various steps have been broadened or curtailed.

Women in Engineering, by Lillian M. Gilbreth. (*Mechanical Engineering, U.S.A., December, 1942, Vol. 64, No. 12, p. 856*).

Personnel and operating phases of women in engineering. Why do women wish to become engineers? War work can be done by women. Are women necessary in engineering? Handicaps faced by women in engineering careers. Advantages enjoyed by women.

FOUNDRY.

Non-Ferrous Foundry Technique, Tin Bronze Founding, by W. J. Treloar and I. Samuels. (*The Australasian Engineer, November 7, 1942, Vol. 42, No. 318, p. 193, 8 figs.*).

1. Metals and alloys. Impurities. 2. Furnaces and melting procedure. Non-crucible furnaces. Furnace atmosphere. 3. Correct range of casting temperature. 4. Moulding and core sands. 5. Moulding procedure. 6. Directional solidification. The assessment of quality in bronze. Density. Porosity. Major porosity. Minor porosity. Shrinkage in cast bronze. Liquid shrinkage. Solidification shrinkage. Negative or inverse segregation.

GEARING.

Gears and Gear Cutting, by Allan H. Candee. (*The Machinist, February 13, 1943, Vol. 86, No. 44, p. 1221, 5 figs.*).

Part III. War Production has created a demand for "instrument" gears, carrying light loads with an unusual degree of precision. Backlash can be varied by adjusting the relative position. Spiral bevel and zerol teeth can be ground after hardening. Zerol pinions of two different diameters are here generated to run with the same gear. Durability important. The whole range of tooth size may be divided into four classifications arbitrarily as follows:

Diametral Pitch
$\frac{1}{2}$ to 2
2 to 8
8 to 32
32 and finer

The range of speed has the following four classifications :

Feet per minute
0 to 80
80 to 400
400 to 2,000
over 2,000

Allowances in gears up, to say, 10 in. diameter run about as follows :

Inspection Limits—inches
0.001 to 0.002
0.0005 to 0.001
0.0002 to 0.0003

KINEMATICS.

A Brief Account of Modern Kinematics, by A. E. Richard de Jonge. [(*Annual Meeting of the A.S.M.E.,* (*U.S.A.*), *November 30—December 4, 1942,* (*Preprint Power Division No. 23*)].

The author has attempted to show what the various problems of plane kinematics are and how they have been approached and solved by simple means so as to make modern plane kinematics a usable tool, not for the mathematician or kinematician, but for the practical engineer. In this respect, the elements of a simple universally usable terminology are given, and the various branches of plane kinematics have been reviewed briefly to give the uninitiated an idea of the great simplicity of the modern methods. Quantitative kinematic synthesis has been presented briefly to the English-speaking engineer for the first time. A few remarks on the graphical methods used in space kinematics are added.

(*Communicated by D.S.R. Ministry of Aircraft Production*).

MACHINE ELEMENTS.

Seals for Anti-Friction Bearings—II, by R. T. Dunlap. (*Power Transmission, February 1943, Vol. 12, No. 133. p. 24, 3 figs.*).

Commercial oil seals, piston ring seals and rotary type seals.

Bearing Metals and Bearings for Internal Combustion Engines, by J. W. Donaldson. (*Met., Ind., January 1, 8, 15, 1943, Vol. 63, Nos. 3,4,5, pages 2, 21, 43*).

A survey of alloys commonly used, properties relevant to their use as bearing metals and uses to which they can be put to obtain the best services. Includes reference to tin economies. Much of the information is taken from recent literature and a short bibliography is given.

(*Communicated by the British Non-Ferrous Metals Research Association*).

MACHINING. MACHINE TOOLS.

The Effect of Hardness on the Machinability of Six Alloy Steels, by O. W. Boston. [(*24th Annual Convention of the A.S.M.,* (*U.S.A.*), *October, 1942,* (*Preprint No. 4*)].

The effect of hardness on the machinability of steel was studied by means of a series of turning tool-life tests on six alloy steels in the quenched and tempered condition. The tool material, tool shape, size of cut, and cutting

fluid represented commercial practice. The results show marked sensitivity of machinability to hardness in all six of the types of alloy steel tested. These steels gave a wide range of machinability ratings, particularly at high hardness. However, the difference in machinability between two heats of the same type of steel was as great as the range covered by the six types. There appears to be a direct correlation of hardenability with machinability of the harder steels.

(*Communicated by D.S.R. Ministry of Aircraft Production*).

Profile Grinding. (*Automobile Engineer, January, 1943, Vol. XXXIII, No. 432, p. 37, 2 figs.*).

The most valuable feature of this machine is the fact that form tools and profile gauges with outlines consisting of straight lines and true radii can be generated from basic data without reference to drawings, templates or projected images. The system employed completely eliminates the difficulty of following a curve by manual operation of two slides at right angles to one another. A semi-skilled operator can produce work that is ready for immediate use without further finishing or lapping. Successful profile grinding depends in great measure upon accuracy in shaping the grinding wheel face. This machine incorporates a diamond truing device which allows the diamond to be viewed through a microscope having a magnification of $\times 25$. Generating geometric outlines. Translatory generating. By means of a simple attachment, the contour of circular form tools can be ground. Built by Taylor, Taylor & Hobson, Leicester.

Down-cut Milling and Back-lash, by H. E. Millington. (*Machinery, February 18, 1943, Vol. 62, No. 1584, p. 182, 1 fig.*).

Schematic sketch of back-lash eliminator for down-cut milling.

CHIPLESS MACHINING.

Sheet Metal Working, by W. S. Neville. (*Aircraft Production, March, 1943, Vol. 5, No. 53, p. 129, 19 figs.*).

Use of rubber dies. Forming long parts. Raising curved flanges. Bending light-alloy sections. Avoiding spring-back. Stretching. Hydraulic stretching press. Drilling.

MANUFACTURING METHODS.

Wright Engine Production, by F. C. Sheffield. (*Aircraft Production, March, 1943, Vol. 5, No. 53, p. 137, 13 figs.*).

Part II. Anti-corrosion treatment of cylinders ; more special machine tools ; gear production ; chip disposal.

Avro Lancaster, III, by Wilfred E. Goff. (*Aircraft Production, March, 1943, Vol. 5, No. 53, p. 111, 31 figs.*).

Tailplane, fin and elevator surfaces ; aileron assembly ; engine sub-frames ; fuel tanks. The tailplane of this large aircraft, with its 33 ft. span is on the scale of single engined aircraft main planes and its manufacture follows similar procedure. Hydraulic control unit. One of the assembly fixtures in which the complete elevator is assembled. Method of attaching the preformed nose-skin to the ribs. The assembly fixture for one complete side of the engine sub-frame. A trunnion mounted jig in which the spar pick-up holes and the engine-mounting lugs are drilled and reamed.

Producing Cartridge Links for Machine Guns. (*Machinery, February 11, 1943, Vol. 62, No. 1583, p. 141, 9 figs.*).

Details of the 0.50-calibre metal cartridge link produced on special machines. Multi-slide automatic cutting, piercing and forming machine used to produce the cartridge link. View of the punch and die members assembled to back-plate of machine. Plan view of die member and stock lay-out showing the operations performed in first three positions. Die set with the punch member removed and with stock placed between two members to show piercing, slitting and blanking work performed on the multi-slide machine by this unit.

Reclaiming Worn Machine Parts by Metal Spraying, by A. J. T. Eyles. (*Mechanical World, February 5, 1943, Vol. 113, No. 2927, p. 133, 7 figs.*).

A roughly cut screw thread provides a good foundation for building up a spray deposit. Steel gives a clearly visible spray—the spray from other metals is not easily seen. Rough turning the worn portion of a machine part preparatory to spraying. Finishing the part by grinding : only a very small cut need be taken. Examples of worn parts which have been salvaged by metal spraying.

Old Machines Rebuilt for War Work, by Herbert E. Fleming. (*The Machinist, February 13, 1943, Vol. 86, No. 44, p. 1224, 4 figs.*).

Using a centralized shop for dismantling and rehabilitating discarded machine tools helps to equip expanding war plants. Overhaul must be thorough. Co-operation from builders. Selecting the plant.

MATERIALS, MATERIAL TESTING.

Plastic Deformation of Metals under Stress, by A. Markin. (*The Australasian Engineer, December 7, 1942, Vol. 42, No. 319, p. 9, 13 figs.*).

Two types of deformation : (a) Elastic deformation. (b) Permanent deformation. Rosenhain's conception of block slipping during deformation. Effect of sensitivity of extensometer on the limit of proportionality of steel tested at 400°C. Law of similarity. Theories of plasticity. Diagrammatic representation of shear stress acting on different planes of a stressed rod. Effect of biaxial tension on flow stress and ductility of steel tubes. The effects of different stresses. Effects of hydrostatic pressures on plastic flow. Effect of stress state on ductility. Stress and strain of single crystals and of polycrystalline aggregates. Slip in zinc crystals. Slip in aluminium crystals. Slip in alpha iron crystals. Slip in other metals. Deformation by twinning. Strain hardening of metals. Changes in properties produced by cold deformation. The mechanical working of metal. The effect of rate of deformation.

The Fluorescent Penetrant Method of Detecting Discontinuities, by Jaber de Forest. [(*24th Annual Convention of the A.S.M., (U.S.A.), October, 1942 (Preprint No. 19)*)].

Cracks and porosity in metals may be located by a suitable penetrating fluid carrying a highly fluorescent dye. When illuminated by near ultraviolet light, the extremely minute quantities drawn into the cracks by capillary attraction are unmistakably identified. The new test is similar to the oil and whiting method, but is far more sensitive and more rapid in application. Only capillary spaces open to the surface can be found, but experience has shown that many vital defects are of this character, expecially in the light metals.

Photographs are shown of typical nonferrous parts commercially inspected by the new method.

MEASURING METHODS AND APPARATUS.

Quality Control in Production Engineering, by H. Rissik. (*Aircraft Engineering, February, 1943, Vol. XV, No. 168, p. 55, 4 figs.*).

Quality control and engineering practice. How quality control benefits production. Some typical results in practice. Quality control results with continuous production. Quality control results with batch production. Influence of quality control on machine shop production. The basic principles. The quality control chart. Statistical stability of a production process. Frequency distribution of piecepart dimension produced by an automatic. Elements of the quality control chart.

Brittle Coatings for Quantitative Strain Measurements, by A. V. de Forest, Greer Ellis and F. B. Stern. (*Journal of Applied Mechanics, (U.S.A.), December, 1942, Vol. 9, No. 4, p.A-184, 14 figs.*).

Particular reference is made to the "stress-coat" materials and method which can effect quantitative analyses within the elastic range by use of brittle coatings alone. In the plastic range, the flaking off of the coating is shown to be caused by a compression component of strain of about 1%. Graphs and illustrations show the effect of such variables as coat thickness, time of dry, temperature and humidity, creep, and bubbles in the coating. Test procedure is outlined.

The Photoelastic Analysis of Transverse Bending of Plates in the Standard Transmission Polariscope, by D. C. Drucker. (*Journal of Applied Mechanics, U.S.A., December, 1942, Vol. 9, No. 4, p.A-161, 8 figs.*).

The ideas of three-dimensional photoelasticity are applied to the analysis of plates under transverse bending, resulting in a simple photoelastic method, employing the standard two-dimensional transmission polariscope. Results of various tests are given ; photographs of two cases, the circular hole and the semi-circular notch, are included. Stress-concentration factors are also obtained and analysed. The problem of the thick plate as contrasted with the thin plate, assumed in the usual theory, is discussed briefly.

PLASTIC MATERIAL.

Compressed Powder Magnets with Synthetic Resin Binder, by H. Dehler. (*Stahl and Eisen, Germany, Vol. 62, No. 47, November 19, 1942, p. 983*).

Permanent magnet alloys of the Fe-Ni-Al type are glass hard and very brittle. They cannot be forged or rolled and the only machining operation possible is that of grinding. The casting of such alloys is also difficult, especially if small holes have to be provided for fitting pole pieces or other attachments. For this reason, powder magnets in which the material is compacted by sintering have been in use for some time.

As an alternative, the author describes a method of compacting by means of a resin binder (about 6% of phenol or polyvinylchloride). By suitably grading the powdered alloy (e.g. 50% 1 mm., 20% .3 mm. and 30% .05 mm. grain size) the density of the compact is of the order of 90% of the original alloy density. (Compacting pressure—1000 atmospheres, hardening temperature —180°C.). This method of compacting enables the ready inspection of fittings or the provision of fine holes. The moulded product comes out true to size and no subsequent machining is necessary. The new process thus lends itself admirably to mass production and the saving in man hours is very considerable.

The magnetic qualities of such powder magnets are within 20% of the corresponding values for the cast material.

It is interesting to note that the new process also enables the production of magnetic filaments by extrusion. Finally by adopting appropriate binders, a magnetic paste or paint can be obtained which has proved useful when additional magnetic fields have to be provided in any arbitrary locality.

(*Communicated by D.S.R. Ministry of Aircraft Production*).

Are You Working with Plastics ? by John Sasso. (*The Machinist, February 27, 1943, Vol. 86, No. 46, p. 1283, 4 figs.*).

Don't try to use tool shapes on plastics that you use for cast iron. They will cut but won't give long life or good finish. Plastics are poor conductors of heat. Therefore, heat generated by the friction of cutting tools has to be carried away by the tool, by air stream or by coolant. Soap used as lubricant. Three-flute taps work best. Use more rake on tools. Cut off at slow speed.

SHOP, SHOP MANAGEMENT.

Management the Simple Way, by Lawrence A. Appley. (*Personnel, (U.S.A.), January, 1943, Vol. 19, No. 4, p. 595.*)

The science of management often appears more complex than it actually is mainly because its practitioners have been prone to invent complexities where none exist. Actually management is "the development of people, not the direction of things," and although individuals differ widely, most human beings react alike to certain situations. 12 facts about human nature are listed that every executive should know. A six-step human relations program is outlined based on those facts.

Training New Supervisors in the Skill of Leadership, by Walter Dietz. (*Personnel, (U.S.A.), January, 1943, Vol. 19, No. 4, p. 604*).

Skill in leading—"job relations training." The foundation of good worker-supervisor relations (1) Treating all people as individuals; (2) Letting people know how they are getting along; (3) Giving credit when due; (4) Giving people a chance to talk over in advance the things that affect them. (5) Making best use of people's ability. How to handle a supervisory problem. (1) Get the facts—be sure you have the whole story; (2) Weigh and decide—don't jump to conclusions; (3) Take action—don't "pass the buck"; (4) Check results. "Good" supervision.

SMALL TOOLS.

Draft in Inches for Die Clearance Angles—III, by W. J. Woodworth and P. T. Woodworth. (*The Machinist Reference Book Sheet, The Machinist, February 13, 1943, Vol. 86, No. 44, p. 1235*).

STANDARDISATION.

Specifications for Nickel and Nickel-base Alloy Products. (*The Machinist Reference Book Sheet, The Machinist, February 13, 1943, Vol. 86, No. 44, p. 1237*).

Tentative specifications—American Society for Testing Materials.

SURFACE TREATMENT.

The Corrosion of Iron and Steel and Problems of Prevention, by V. C. J. Nightingall. (*Journal, Institution of Engineers Australia, November, 1942, Vol. 14, No. 11, p. 253, 5 figs.*).

Electrolytic theory of corrosion. Examples of corrosion. Stifling of galvanic corrosion by effects of deposit inside of pipe. Rivet heads of a rusted pipe. End plate of a cooling water system of a motor bus. Centre button of gun metal acting as cathode, aluminium alloy acting as anode. Effects of wrong dissimilar metal design—aluminium alloy against copper. Pickling and de-scaling. Differential aeration. Polarization. Laboratory tests. Protective coatings. Galvanising. Cathode protection developments.

TECHNICAL INFORMATION.

World Production of Aluminium in Metric Tons. (*Metal Statistics, 1939 (U.S.A.), p. 503*).

Figures are in units of 1,000 tons.

	1933	34	35	36	37	38
Germany	18.9	37.2	70.8	97.5	127.5	175.0
G.B.	11.0	13.0	15.1	16.4	19.4	24.0
Canada	16.2	15.5	20.6	26.9	42.6	50.0
U.S.A....	38.6	33.6	54.1	102.0	132.8	130.1
France	14.3	15.1	22.0	28.3	34.5	40.0
Japan	—	.7	4.0	6.7	10.5	15.0
U.S.S.R.	4.4	14.4	24.5	37.9	45.0	50.0
Switzerland	7.5	8.2	11.7	13.7	25.0	28.0
Italy	12.1	12.8	13.8	15.9	22.9	28.0

According to American Aviation (October 1, 1941), p. 19, the U.S.A. production for 1943 is estimated at 300,000 tons.

(*Communicated by D.S.R. Ministry of Aircraft Production*).

World Production of Magnesium in Metric Tons. (*Imperial Institute, Mineral Resources Dept., Report on Magnesium, 1939 (Gr. Br.), p. 23*).

	1933	34	35	36	37	38
Germany		Figures not available			12000	14000
G.B.		Figures not available			2000	3000
U.S.A....	641	1897	1893	1743	2000	3000
France	128	241	419	1365	1800	2000
Japan	103	139	350	650	1200	1500
U.S.S.R.		Figures not available			700	1000
Switzerland		Figures not available			230	300
Italy	—	—	—	—	70	200

According to American Aviation (October 1, 1941, p. 13), the U.S.A. production of Magnesium is estimated at 10,000 tons for 1941 and an output of 100,000 tons is hoped for by 1943.

(*Communicated by D.S.R. Ministry of Aircraft Production*).

WELDING, BRAZING, SOLDERING.

The Use of Spot Welding in Design and Production of Aircraft, by J. S Mikhalapov. (*Welding, January, 1943, Vol. 11, No. 2, p. 47*).

A detailed survey of the present position of spot welding in aircraft manufacture in the U.S.A. (this is a paper read recently at the National Aircraft Production meeting of the Society of Automotive Engineers at Los Angeles.

(*Communicated by the British Non-Ferrous Metals Research Assoçiaion*).

Weld Forging—An Aid to Production, by J. Winning. (*Mechanical World, February 12, 1943, Vol. 113, No. 2928, p. 159, 6 figs*)..

Methods of combination to exploit the best features of both welding and forging. Practical examples. Universal joint assembly: the kind of job which is complicated if done entiıely as a forging, but which is relatively simple by weld-forging. Weld between solid shaft and disc. Weld between hollow shaft and disc. Defects of all-forging method. Result of forge-welding. A gear wheel assembly. A bracket which, if forged in one piece, would consume much excess material, but which, by a welding process, saves both material and time. Choice of welding process. Smelting effects.

WELFARE, SAFETY, ACCIDENTS.

Assistance to Employees during Sickness. (*Industrial Welfare, January, February, 1943, Vol. XXV, No. 286, p. 18*).

Insurance against anxiety. The short illness. Some methods of sickness payment. Deductions from sickness pay. Prolonged illness. Transferred workers. Rehabilitation. The worker who has suffered a long or severe illness needs careful " nursing " back to work.

WOODWORKING.

Plywood in Aircraft Construction, by G. A. Allward. (*Annual Meeting of the A.S.M.E., (U.S.A.), No. 45, November 30—December 4, 1942, Preprint No. 45*).

Shortage of aluminium has forced aircraft manufacturers to turn to alternative materials, and since plastics are as yet unsuitable for structural parts, a return to wood in aircraft construction is clearly indicated. Unfortunately, the aircraft wood worker has by now almost completely disappeared from the industry and whilst a wealth of information is available covering metal structures, comparable information on wood is extremely meagre. As a result the conversion task is very formidable, but it is hoped that with the extra steps now being taken, the lack of information will be remedied in the near future. It is, however, already clearly apparent that resin bonded plywood offers the best form of wood for aircraft structure of the shell type. On account of its low density the effective shell thickness, (i.e. total cross-sectional area, skin plus stringers, divided by circumference of body) of the plywood structure may amount to 4 or 5 times that of the dural shell of the same weight. A dural compression panel is normally designed to support about 1500 lb. p.s.i, (Limit is given by panel buckling). The plywood panel of same strength-weight. ratio should therefore withstand about 4,000 lb. p.s.i. for a thickness of about .2 in. Experiment shows that this needs a stringer spacing of about 8 in. but for mass production purposes it may be advisable to increase this spacing to use a slightly thicker skin (+ = .3 in. increases the necessary spacing to 45 in.). This increase in thickness has the further advantage that the torsional stiffness of the shell is increased very markedly. Plywood is easily formed in a steam chamber so that an entire fuselage covering can be produced as two half shells. In the case of the Clark Model 46 aeroplane, only 18 man hours are required to fabricate one half shell (fuselage 20 feet long, 6 feet diameter).

The plywood shell elements of a wooden structure are thus well adapted for mass production besides possessing the attribute of an efficient structural material.

In converting structural parts from metal to wood, experience has shown that properly designed parts will weigh less than the metal parts they replace and in most cases possess superior stiffness.

A further advantage is the absence of corrosion whilst satisfactory surface finishes for weather protection are already available.

Making Plywood with Multidirectional Pressure, by John S. Barnes. (*Mechanical Engineering,* (*U.S.A.,*) *January, 1943, Vol. 65, No. 1, p. 17, 5 figs.*).

What is moulded plywood? Simple or compound shapes may be formed. Problem of forming compound-curved surface. Knowledge of wood technology essential. Calculating pressure required. New resins give full-strength bonds. Publicity on new process misleading. Further development of moulding technique necessary.

THE INSTITUTION OF PRODUCTION ENGINEERS

36, Portman Square, London, W.1

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SURFACE FINISH

Report of the Research Department of the Institution of Production Engineers, 36 Portman Square, London, W.1.

by DR. GEO. SCHLESINGER, *Director*.

January, 1942

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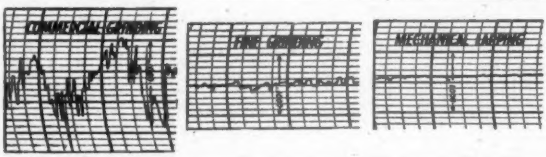
CONTENTS

Principle factors involved. Results of measurements. The influence of the scratching action of the stylus of tracer instruments. (a) Classification of surfaces without measurement. (b) Quantitative photomicrography. Dimension and surface roughness of gauges. The instruments used. Investigation of surface roughness in the U.S.A.



Showing Quality of Surface and Manufacturing Process.

Review from MACHINERY—*England, April* 16, 1942.

The subject of surface finish in relation to dimensional accuracy, fit, lubrication and wear of operational components has been one of the most important questions that have occupied investigators in recent years on both sides of the Atlantic.

One of the chief problems has been the quantative determination of the amount and conditions of surface finish and a unit of roughness.

The results presented in the report make a most important contribution to the development of a technique of basic importance in engineering production, and, in a remarkable table occupying 48 pages, the findings are collected and compared in respect to 500 surfaces of all kinds.

The aims of the research, the chief of which was to replace the loose descriptive methods by a more definite system for measuring surface roughness, appear to have been completely reached.

Review from ENGINEERING—*July* 24, 1942.

The importance of the matter, and, no doubt the very complete basis for a consideration of the subject which is furnished by this report, has led to the appointment of a committee of the British Standards Instutition to consider the formulation of standards.

For the purposes of this investigation the Institution appealed to a wide range of manufacturers of the finer grades of engineering product and obtained typical specimens of finished work from 19 British firms. The most important instruments, both for the measurement of surfaces and for their comparison, were also lent by British and American makers.

Those who have hitherto given little attention to the matter will find the report an admirable guide to the whole subject of surface finish.

Review from AIRCRAFT PRODUCTION, *May* 1942.

Although engineers have realised for some considerable time the importance of the quality of surface finish for both moving and static parts, practical engineering data and technical literature have not hitherto been available for those interested. Consequently the Research Department of the Institution of Production Engineers are to be congratulated on their foresight in making the first thorough investigation of the subject in this country. The results of the experiments have been collected and arranged as practical, useful measuring units in a table giving data describing approximately 500 surfaces of all types. The instruments used for measurement included the most modern tracer and optical apparatus.

Review from MECHANICAL ENGINEERING—*July* 1942 (*American Society of Mechanical Engineers*).

Dr. Schlesinger's book is particularly welcome because it is one of the few books in the English language on the timely subject of surface finish and because it brings together much new and hitherto unpublished information.

The study was undertaken to provide standards for the measurement and rating of metal surfaces and to summarise standard practice in Great Britain as regards the type of finish which is applied to various machine parts by reputable manufacturers.

The tabulation of the results of these measurements in the last 48 pages of the book is one of its most valuable features.

One of the most interesting sections of the book deals with the tolerances and finishes on plug and snap gauges and on gauge blocks. The finish measurements on these tools are quite enlightening.

STEWART WAY, *Research Laboratories, Westinghouse Electric Mfg. Co., East Pittsburgh*

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